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CONTENTS

Production of High Chromium Alloy Steel 334
Manufacture of High Chromium Alloy Steel in Acid Lined Furnace Described—With Proper Care, Acid Furnaces are as Satisfactory as Basic
By R. S. KERNS

Steelwork Found in Excellent Condition 337
Structural Framework of Madison Square Garden, Except for a Few Unprotected Places, Found in Almost Perfect Condition After 35 Years of Service
By FRANK W. SKINNER

Protective Coatings for Metals 341
The Last of a Series of Educational Articles Dealing with Various Methods for Protecting Metal Surfaces Against Corrosion and Oxidation
By JAMES A. AUPPERLE

Selection of Coals for Coke Manufacture 344
A Discussion of Physical and Chemical Characteristics of Coal for the Manufacture of Blast Furnace, Foundry, and Water-Gas Coke in By-Product Ovens
By H. J. ROSE

General Principles of the Beneficiation of Iron Ores 350
By T. T. READ

Bibliography of Manganese Steel 361
By VICTOR S. POLANSKY

Molybdenum as an Alloying Element 365
Heat Treated Molybdenum Steels Possess High Elastic Limit, Reduction of Area and Impact Value and Great Durability When Subjected to Abrasive Wear
By JOHN D. CUTTER

Plant Visitation Helpful 333
Locomotive Ashes for Fuel 336
Oil-Electric Locomotives to Enter Industrial Field 356
Carnegie Issues Books 357
World's Largest Blooming Mill Completed 358
To Study Mining and Metallurgy 360
Watt's Workshop Saved 360
Inspects St. Louis Stack 367
Receiver Named for Dominion Steel 367
A. S. S. T. Announces Tentative Program 367
Building Project Outlined by Westinghouse 367
New Equipment Section 368
Personals 370
Obituaries 372
Industrial Business Changes 372
Trade Notes 372
Coming Meetings 373
Trade Publications 373

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The Blast Furnace and Steel Plant

Vol. XIV PITTSBURGH, PA., AUGUST, 1926 No. 8

Plant Visitation Helpful

MANY industrial executives, in order to get ideas on methods and operations of various concerns, have found that it pays to afford their engineers an opportunity to visit other plants. This practice, beyond question, has a broadening influence upon men who are capable of observing new methods and absorbing novel ideas when they pass through a plant, and then apply what they have seen to their own problems. The time and expense of the visit will be well repaid for one valuable idea or suggestion obtained in this manner.

An individual visit is much more valuable than the shop visits frequently arranged in connection with conventions. It is difficult to obtain much real information when an individual is conducted through a shop with a large number of other men, although such visits are well worth the time if it is impossible to spend the necessary time and money for an individual visit. Such visits are best arranged by correspondence, for in this way the visitor will meet the right man when he arrives, and without wasting any time, he will have an opportunity to observe the operations and equipment that will be helpful in his work. Most plants are willing to cooperate in this manner, and by doing so they give the visitor an opportunity to study methods and equipment similar to those used in his own plant. The advantages that are derived are usually beneficial.

Production of High Chromium Alloy Steel*

Manufacture of High Chromium Alloy Steel in Acid Lined Furnace Described—With Proper Care, Acid Furnaces Are as Satisfactory as Basic

By R. S. KERNS*

HEAT resisting alloys have been on the market for some time. The demand growing out of the manufacturer specifying castings to give better results and longer life in the transmission of high temperature corroding liquids and gases, in the parts of annealing furnaces exposed to stresses under high heats, and, in fact, any place where the plain carbon steel casting has to be replaced frequently on account of its inability to resist high temperatures, that is up to 2200 deg. F. and still be serviceable.

Various alloys have appeared on the market during the past four or five years under various trade names, and each one has shown that it is able to withstand the abuse to which it is subjected day by day. The writer does not wish to dwell on the merits of the different heat resisting alloys, and will therefore enumerate some of the uses to which these alloys have been adapted.

In the oil refinery it has been found highly successful in the transmission of hot liquids and gases. The tubes used for this purpose are in many cases subjected to the action of flames as well as the action of hot liquids. The headers must also be able to withstand this punishment and yet retain their shape as well as resistance to oxidization.

In the annealing furnaces the alloys have found use in the disks of continuous annealing furnaces as well as the bottom, sides and roof. H and I beams of these alloys, either cast or rolled, are used where articles are placed in the furnaces on racks. Cyanide pots and annealing boxes have shown remarkable life when made from these alloys.

Dish valves in the gas lines of open hearths when made from these alloys show a greater life, less warpage and burning away, than valves of cast iron or steel. In fact, as stated before, almost every place where carbon steel or cast iron has proven inefficient in contact with high heat, these alloys are slowly creeping in. The advantages claimed for the alloys being their ability to resist oxidation and chemical reaction, and a minimum deflection when loaded and under high heat.

Composition of Heat Resisting Alloys.

The majority of these heat resisting alloys contain a large percentage of chromium, some of them going as high as 30 per cent chromium, and others from 15 per cent up. Some of the alloys also contain nickel in varying amounts from 3.50 to 36 per cent. The carbon in most cases running from 0.20 to 0.60 per cent. However, one company producing high chromium heat resisting alloy has found by extensive investigations that the presence of nickel is harmful when the casting is exposed to open flames, especially where much sulphur is present in the fuel, the claim being that the sulphur in the flame combines with the nickel, forming a nickel sulphide. When the alloy is exposed to the sulphur and this sulphide formed, the casting has a tendency to swell and assume a rough warty appearance. Continued contact with the open flame destroys the properties of the nickel bearing heat resisting alloys.

In the nickel-sulphur equilibrium diagram it will be noticed that each addition of sulphur lowers the melting point of nickel. However, in the electric annealing furnaces, nickel does not seem to harm the alloy, but instead, seems to impart additional strength to it, only when used in amounts of 3.50 per cent or over; below this amount there does not seem to be any appreciable difference in the physical properties of the alloy. This fact was discovered by the writer when melting and producing one of the high chromium heat resisting alloys recently in an acid electric furnace.

Chromium has been used for some time in the production of stainless-steels. It has been found that the non-corrosive properties are due to the stabilizing of the passive state of the steel by the chromium. This, however, is not accomplished unless the chromium is at least 15 per cent. Another theory advanced as to the properties of high chromium steel is that, up to a certain composition, a solid solution behaves toward reagents as does its noblest constituent.

This now gives the basis for working up a heat resisting, non-corrosive alloy. First, an alloy added to the steel which will impart to the casting or shape the ability to resist corrosive action on flames; this has been shown to be chromium in sufficient quantities. Second, the final product must be strong and able to hold its shape under long exposure to high heats, that is from 2000 to 2200 deg. F. With the carbon around 0.20 to 0.60 per cent and the chromium of a correct percentage, the product has this second property and will not warp or crack as does plain carbon steel or grey iron castings. It has been proven that with an increase of chromium in carbon steel the Ar and Ac points of hypoeutectoid steel will be raised. In other words, the temperature range of grain growth has been raised which imparts to the steel the property sought.

Melting Operation.

The composition of the particular heat resisting alloy which the writer wishes to discuss was as follows:

Chromium	25.00 to	30.00	per cent
Carbon	0.40 to	0.60	per cent
Silicon	not over	0.50	per cent
Manganese	0.60 to	0.80	per cent
Sulphur	not over	0.05	per cent
Phosphorus	not over	0.05	per cent

The writer had produced this alloy successfully in a basic lined electric furnace with a rated capacity of 1,000 lbs. and was called upon later to see what could be done in an acid lined electric furnace of greater capacity. The second furnace was a 3,000-lb. Pittsburgh Electric Furnace Corporation installation.

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Due to the fact that we were using an acid lined furnace and to general working conditions we were preparing to lose a large percentage of chromium in the slag. The representative of the company who was selling the alloy advised the writer to provide for at least an 8 per cent loss of chromium. However, after he had observed the care taken in melting a heat of regular carbon steel, it was decided to allow for a 4 per cent loss of the alloy; in other words, the charge was calculated to contain 32 per cent chromium as charged to yield a 28 per cent chromium product. As a 1 per cent carbon ferro-chrome was used it was necessary to use only low carbon scrap. The scrap was accordingly selected from a pile of 0.12-0.15 per cent carbon stock and a charge of 3,000 lbs. made up as follows:

1 per cent ferro-chrome	1,371 lbs.
.12-.15 carbon scrap	1,662 lbs.
Total	3,033 lbs.

As almost one-half of the charge was ferro-chrome, the problem of charging it was next brought up. It was decided to charge some of the scrap on the bottom of the furnace, then charge some ferro-chrome, then more scrap and more ferro-alloy, keeping the alloy in the center of the furnace as much as possible to protect it from the air during the melt down, and finally the remainder of the scrap. This method had worked very well in the small furnace, but with the larger furnace we were headed for difficulties. The scrap melted and allowed the ferro-chrome to sink to the bottom of the furnace, forming a skull. It was some time before we were able to get the bottom cleaned off.

We were fortunate to receive about 50 lbs. of slag from some former heats of this alloy which had been produced in another foundry. This slag was saturated with chromium and the idea was to form a slag at the beginning of operations containing a large percentage of chrome in order to hold more chromium in the bath. It seemed that the slag would absorb a certain amount of chromium and if a slag could be formed at first containing a large percentage of the alloy the loss in the heat would not be so great. About 30 lbs. of the slag was used in this heat, being charged with the scrap and ferro-alloy.

The power was thrown on and all the openings lutted up with clay. It was essential to keep out as much air or oxygen as was possible and attempt to maintain as near a neutral atmosphere as we could. Lime was used freely on the slag but not enough to harm the lining. Power was used for about 40 minutes at the rate of 1800 amps. and 135 volts, then a lower voltage was used of 80 volts and about 2400 amps. After about 90 minutes the door was opened to observe conditions in the furnace and to take a temperature test. It was then discovered that the bottom had a heavy skull and no heat test was taken. After 30 minutes longer the bottom was again tried and finally after about 2½ hours after starting the heat the bottom was clean.

Judging the Pouring Temperature.

It is important that the pouring temperature of this alloy be correct, it must not be poured too hot or too cold. Of course the pouring temperature is influenced somewhat by the class of the work and the methods of handling of the material or metal. It is the temperature of the steel when poured into the mold that has to be watched. In other words, the time required for the metal to set has much to do with the resulting physical properties.

Two methods of getting the temperature of the metal in the furnace are as follows: First, by the skim test as used for plain carbon steels, the difference being that one half of the time required for plain carbon steel to skim over is considered a good pouring temperature for the alloy. In other words, if it is practice to hold plain carbon steel 60 seconds for a freeze-over, then 30 seconds will be sufficient time for the alloy and it will pour with the same fluidity as the 60 second carbon steel.

The second method is by observing the fracture of a test piece. When the alloy is cold the fracture resembles somewhat that of tool-steel, being an extremely fine grain. As the temperature is increased the grains grow until at a 30 second skim test they are large, perfectly smooth and bright, and arranged in a regular formation with regards to the contour of the test piece. Grains as long as one-quarter to three-eights of an inch and one-sixteenth to one-eight of an inch wide were secured.

One of the problems of the melter is then to get the alloy at a temperature high enough to give the required fluidity and yet cold enough to keep the grains as small as possible, as the large grains, which fracture along well defined cleavage planes, affect the ultimate strength of the castings.

Let us go back again to the first heat and some of the peculiarities of this alloy. When we looked in the furnace the heat was lying perfectly quiet. In fact it had a dull, dead appearance, as did the heat test when removed from the furnace. No silicon or killer was necessary, this was due to the large amount of silicon to be found in the ferro-alloy, it being about 1 per cent in the ferro-alloy we were using. About 25 pounds of ferro-manganese was added to the furnace when we had finally gotten the correct pouring temperature and three minutes later the ladle was called. This met with a vigorous objection from the foundry superintendent as he said it was too cold to run out of the furnace. Surprises were in store for him later on.

The heat was tapped into a 4,000-lb. ladle and set on a stand where it was distributed to the molds by means of a 500-lb. bull ladle. The heat as poured had a sluggish, dead appearance but showed no tendency to freeze. After several of the castings were poured one of the molds broke out as it was being poured. A shovel of sand was held against the stream but the metal flowed as fast as before, a shovel of wet sand was then tried with no better results, clay would not freeze it up, in fact the only method the writer has found to stop a break out of the alloy is to hold a stick of aluminum in the stream, this will cause it to set provided the stream is not too large.

By this time the superintendent was prepared to see anything. Here was a heat, to all appearances so dead and sluggish it looked impossible to pour die blocks with but was so hot it broke through the mold and defied wet sand or clay to cause it to freeze. When the heat was poured there was no trace of a skull in the large ladle or in the bull ladle.

In running the analysis the next day, the writer found the chromium content to be 31.6 per cent, and thinking there was some mistake a sample was sent to the company selling the alloy, to check the result, they reported 31.62 per cent chromium. So instead of losing at least 4 per cent chromium the loss was only 0.38 per cent. Accordingly, in the following heats we figured on 30 per cent chromium in the charge to produce a 28 per cent product, but results were so good that we were finally able to base our charges on 29 per cent chromium going in and getting 27-28 per cent in the product.

It was apparent from this first heat that a different method of charging the ferro-alloy was essential, so as to escape the skull in the furnace. This was done by charging about 30 per cent of the alloy with the whole charge of the steel scrap and letting this melt down under as limy a slag as was possible to carry in the acid furnace. The remainder of the alloy was added a shovel or two at a time at regular intervals of three or four minutes. This resulted in a shorter time for the heats, and yet the final analyses were within the limits. When the final shovelfull was thrown into the furnace, the furnace was sealed up as before and sufficient time given to be sure it was all melted and about hot enough when the seals were broken and heat tests were taken.

It might be added here that when nickel was added to the heat it altered the fracture somewhat. The fracture was then very fine grained even when the heat was at the correct pouring temperature. It was also possible to bend the test piece, which was 1½ by ¾ by 5 inches long, from 30 to 60 degrees before rupture. The steel containing chromium alone was very brittle, this fact prompting the writer to add nickel to the alloy. It was then found that at least 3.50 per cent nickel was necessary to change the structure of the alloy.

A few words concerning the slag would probably not be out of place at this time. When everything was going according to Hoyle, the slag had what we called a snake-skin appearance. When the slag was taken from the furnace and cooled it had a tendency to shrink and present a wrinkled appearance while the color was a brownish green looking very much like a piece of leather or snake-skin. The slag when poured into a basin in the sand so as to be about four or five inches thick, when broken up had a very dense structure. Some times the slag fracture would be a dark blue and shine, and at other times it would be a dull green, and again we had slags which showed both the blue and green fracture, there being a sharp line of demarcation between the two different colors. The laboratory did not have the necessary equipment to run an analysis on these slags so that compositions of them were unknown, however we did find that the chromium content always came within the limits set.

Cleaning Room Troubles.

As the castings were brittle when they contained no nickel, it meant very careful handling until they were annealed. The larger castings of from 75 to 200 pounds were provided with fairly large sink heads, and when the employee in the cleaning room attempted to cut the heads off with the oxy-acetylene torch, he was surprised to find the flame had no effect on the casting. After changing the tip and flow of oxygen he was finally able to get the heads melted off with a very ragged cut. The alloy was surely living up to its reputation as being able to resist an oxidizing flame. For the following heats a head was provided with a V-notch where the head joined on the casting. It was then possible to knock the head off with a sledge hammer and not injure the casting.

Care was also necessary in snagging the castings, for if the casting was burned with the wheel a hard spot resulted. It was therefore necessary to resort to wet grinding. While the metal was brittle, yet it machined like grey iron on both thick and thin sections. It was always easy to tell on a machined surface where the snagger had heated the casting as it would show up in a "nigger head" or hard spot. The additions of nickel did not affect the machining qualities of the castings.

Conclusions.

After several heats we were able to standardize the practice as to: Charging the ferro-chrome, adding about 30 per cent of the ferro-alloy with the scrap charge and the remainder in small quantities at short intervals. Judging the pouring temperature, by means of the skim test when nickel was used and by the fracture when no nickel was used. Pouring the castings, at no time allowing the stream of metal entering the mold to stop, after we found that when there was an interruption in the flow of metal the alloy would not knit or fuse together as it does in cast iron or carbon steel. The casting then resembled steel poured cold, having a fold-over where the metal did not unite. Grinding the castings carefully, to guard against burning which produced hard spots.

It is the writer's opinion that alloy steels can be produced in an acid lined furnace as satisfactorily as in a basic lined furnace when proper care is exercised. Manganese steel being the exception as this is a basic furnace product.

Locomotive Ashes for Fuel

Remarkable improvements in methods for conserving fuel have been made by railroads in the last few years. Indications are that still greater savings may be possible by other means than any used in the past. It very often happens that a discovery which seems of practically no importance, results in remarkable savings.

German engineers have found that by mixing cinders collected in locomotive smoke-boxes with good coal, it is possible to effect considerable savings in the consumption of fuel. It is estimated that the average yearly saving from the use of this reclaimed fuel on German railways will amount to approximately $1,327,000. Tests conducted in the burning of such fuel on German railroads indicate that the fuel has a heating value of 8,100 Btu. and that an average evaporation of 7.06 pounds of water may be obtained per pound of fuel.

The Boston & Maine Railway has under construction a plant for reclaiming coke from locomotive ashes. This reclaimed fuel is to be used for station heating purposes, and it is estimated that here will be a saving effected of approximately 30,000 tons of coal each year.

This plant is reported to be the first of its kind in this country, and no doubt if its operation is as successful as anticipated, its introduction will mark the beginning of a new period in the conservation of fuel. Moreover, it seems that if this fuel is suitable for use in stationary power plants, it would be reasonable to assume that a certain portion mixed with good fuel might also be used on locomotives.

If the German railways can save approximately $1,327,000 a year by using coke reclaimed from ashes as fuel, and if the Boston & Maine realizes a saving of 30,000 tons of coal a year, it would seem possible that the more general use of these two methods would effect material savings on all railroads.

Steelwork Found in Excellent Condition*

Structural Framework of Madison Square Garden, Except for a Few Unprotected Places, Found in Almost Perfect Condition After 35 Years of Service

By **FRANK W. SKINNER**†

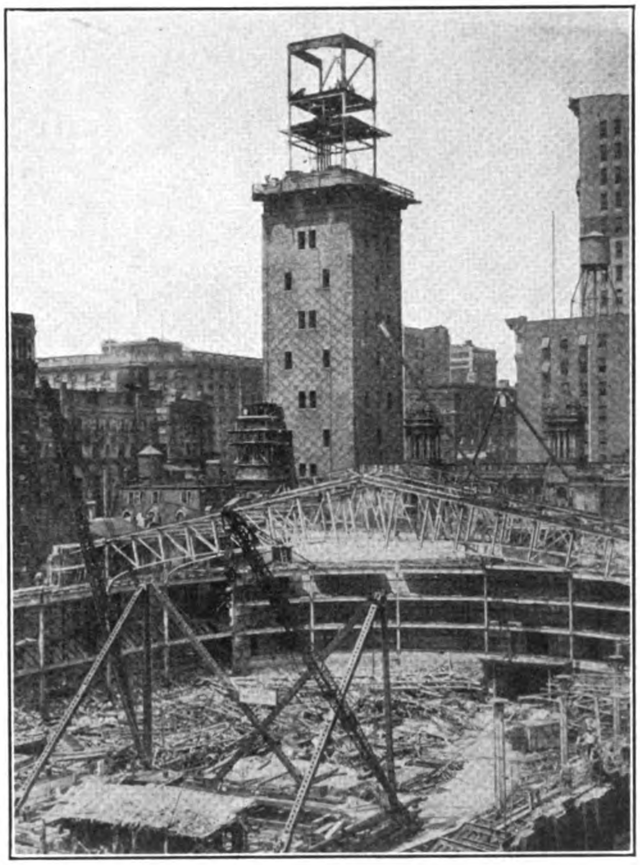
THE structural framework of Madison Square Garden was fabricated at a time when both wrought iron and steel structural shapes of the same dimensions and patterns were on the market in large quantities, probably more iron than steel being then fabricated. Since the Garden was built, both the architects and engineers have moved their offices one or more times and many of their records have been destroyed by fire, lost or abandoned, so that efforts have entirely failed to disclose any information regarding the steel that was stated in current descriptions of the work to have been used for part of the construction. No specifications and no mill orders have been found. Bending, breaking and chemical tests made of available samples from angles and small pieces indicate wrought iron, but portions of the main trusses very closely resembled steel and it was the opinion of several engineers who inspected them and of the experienced superintendent who removed them that they were made wholly or in large part of steel, but that many or all of the I-beams and small pieces were wrought iron. In most cases the behavior and appearance of the metal might indicate either iron or steel.

The main outer brick walls, 40 ft. high from street to roof, rested on 28-inch brick foundation walls 10 to 30 ft. deep with concrete footings. Partition walls were of hollow tile in cement mortar. The main tower of brick surmounted by a slender steel framework carrying the statue of Diana, was 38 ft. square. The roof trusses, beams and columns were of wrought iron and structural steel in proportions now unknown. The floors and roofs except that over the arena, were supported on short span wall bearing I-beams; most of the doors were iron, and the construction, although considered when designed to be fireproof due to the minimum use of combustible materials, lacked the protection usually given all steelwork.

The tile and concrete floors were supported on wall bearing I-beams. The lower part of the steel framework in the main tower was solidly built into the brickwork, but above the top of the masonry it was sheathed with copper.

The most interesting and conspicuous part of the framework construction was the 167 x 277 foot oval roof, about 75 ft. in extreme height above the floor of the arena. It had six main transverse trusses and sixteen radial end trusses carried on 28 independent Phoenix columns about 50 ft. long. The top chords of the trusses were connected by 12 in. 32-lb. I-beams carrying 4 in., 18-lb. I-beam purlins parallel to the trusses, that supported the wood planking under the tar and gravel surface. The arena was lighted by two 26 x 55 foot fixed end skylights and ten intermediate 26 x 26 foot rolling skylights together covering the 55 x 135 foot central space that could be completely opened.

The pin-connected roof trusses were all of similar design with depths varying from about 6½ ft. at the first panel point to 10½ ft. at the center and having trough shape top chords. The radial trusses had the same dimensions as the semi-trusses of the main transverse spans and were supported at their converging ends by top chord connections to semi-drums and by bottom chord bearings on shelf angles on the end transverse trusses. The semi-trusses of each transverse span had the bottom chord eyebars in the adjacent center panels connected by short plate links with a chord pin in each hand. These links were undoubtedly, and the remainder of the trusses were probably of steel. The vertical end posts of all trusses had roller bearings on the tops of six section iron Phoenix columns about 12 ins. in diameter each made in four one-story lengths with transverse horizontal connection plates at balcony floor levels. The columns were seated, below the basement levels, on high cast iron pedestals with well proportioned concrete footings.


Three stories of the tower and a large portion of the roof over the arena removed. The Phoenix columns which supported the roof trusses are seen in the foreground. All steelwork shown in the illustration, though unprotected, was in good condition. Much of it will be used again.

The razing of the Garden was commenced May

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†Consulting Engineer.

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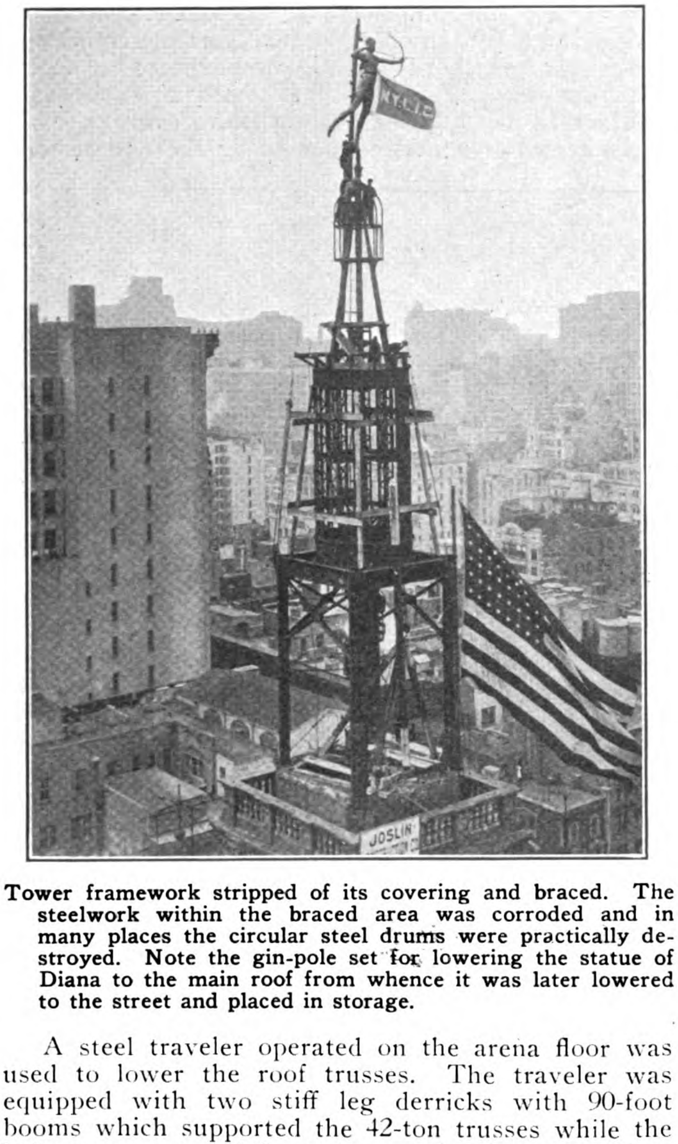
6, 1925, and the structure was removed to the street level in about four months. Operations were begun on the main tower where the stripping of the copper sheathing and brickwork enclosing the upper part of the framework showed some of the girders to be in such bad condition that a four post pyramidal wooden false work 35 ft. high was set on top of the rectangular main framework to give support to the circular drums carrying the apex of the tower and the statue. A 35 foot wooden gin-pole was installed on the upper drum and with it the 1400-lb. statue made of riveted copper plates was lowered. The remainder of the tower framework was removed by means of the gin-pole and a jinniwink derrick.



Tower framework stripped of its covering and braced. The steelwork within the braced area was corroded and in many places the circular steel drums were practically destroyed. Note the gin-pole set for lowering the statue of Diana to the main roof from whence it was later lowered to the street and placed in storage.

A steel traveler operated on the arena floor was used to lower the roof trusses. The traveler was equipped with two stiff leg derricks with 90-foot booms which supported the 42-ton trusses while the bolts were removed from the top chord center splices and the bottom chord center connection links were cut with oxy-acetylene torches, and then lowered the semi-trusses successively. Later bridles were connected to each semi-truss at four points and it was moved with the web horizontal with little deflection and pilled up awaiting transportation to storage, great care being taken to avoid any injury or distortion of the trusses which are to be re-erected for permanent use in a new building.

Except for the main truss pins, all field connections were found to be bolted instead of riveted, and in some cases half or more of the holes in the field connection were found open. The bolts were in excellent condition except that the threads were rusted tight, making it generally necessary to burn off the heads in order to remove the bolts. The remainder of the framework was taken down with stiff leg derricks and jinniwinks.

The structural framework had been fabricated and erected with the same care shown throughout the building. All of the structural iron and steel, except a relatively small proportion under special and unusual conditions in the main tower, was found in a perfect state of perservation, of unimpaired strength and excellent appearance after more than 35 years of service with little or no apparent care for its maintenance. None of it had been protected except where it happened to be enclosed or partly enclosed in the brickwork or floor slabs and there was little evidence of periodical painting except perhaps for the columns and other metal exposed in the balconies.

Many of the beams and braces and all of the roof truss purlins and rafters showed no traces of painting after erection, with the exception of the skylight girders and framework which were poorly protected and severely exposed to the weather and showed considerable corrosion in places. All the roof members, especially the main trusses, were in good condition and scarcely discolored by rust except in a few bearings.

Although the upper surfaces of the top flanger of the 4-in. I-beam purlins supporting the main roof planks had apparently never been painted, the metal was generally clean and bright with only occasional rust stains and no pitting or material corrosion. The webs and bottom flanges were well protected with what was apparently the original shop coat of paint still in good condition. The 2½-in. T-bar purlins supporting the tile roof over the upper gallery showed no signs of corrosion. The beams embedded in the gallery floors also showed no signs of corrosion.

Painted I-beams bearing in the corners of the outer walls, above the roof, to support the minarets, although fully exposed to the weather were practically free from corrosion except where the ends penetrated the brickwork and were slightly rusted.

The Phoenix columns which were well painted on the outside and had both ends tightly closed by the end bearings were in perfect condition outside and, as well as could be seen when exposed, in equally good, uncorroded condition inside. A large number of I-beams were wall bearing, many of them were inspected where they had penetrated and rested on the masonry and none of them showed serious corrosion; very few showed more than a trace of rust or discoloration or roughness.

The lower flange angles of the roof truss portal braces had connections several feet long against the vertical faces of the vertical end posts of the trusses and these contact surfaces on both members as well as the contact surfaces of hitch angles in beam and girder connections had been unpainted, and were generally bright and clean except in a few cases where they showed light rust or rust stains. In general the surfaces of field joints, sometimes 2 or 3 ft. long and wide, although unpainted were clean and bright.

In the upper part of the main tower the framework was subjected to very severe, destructive and wholly improper conditions entirely different from those affecting the steel and iron in all other portions of the Garden. Notwithstanding this fact, and the obviously total lack of attention and maintenance, this (apparently iron) structure resisted destruction to such a degree as to continue to perform its structural funcions for 35 years.

Above the top of the brick walls the iron framework simply supported the ornate architectural members and were enclosed not closely covered as with a molded skin, by the hollow columns, bases, panels and mouldings of the architectural embellishments. This envelope was made of sheets of copper fastened to a light iron furring secured by angle clips to the main framework.

When the statue of Diana was removed no corrosion or other deterioration was observed on it, or its base or in the ball bearing which supported it; there were no evidences of electrolysis where the different metals were in contact, and for a distance of about 30 ft. below the statue the copper sheathing was intact, there being no holes in it; the framework it covered was not corroded, and that part of the structure was in good condition.

From the foot of this undamaged section, at the level of the upper circular girder, for a distance of about 35 ft. down to the lower circular girder or drum on top of the rectangular tower framework, many holes were found through the copper sheathing and the enclosed framework was badly injured by corrosion or electrolysis or both. Some of the rivets attaching the copper sheathing to the light furring were found in good condition while the furring was entirely gone, leaving only the flanges of some 7-in. circular channels. Some beam connections had completely rusted away so that it was necessary to brace and wire the remaining pieces of the framework together before commencng the critical operations of disconnecting and removing it.

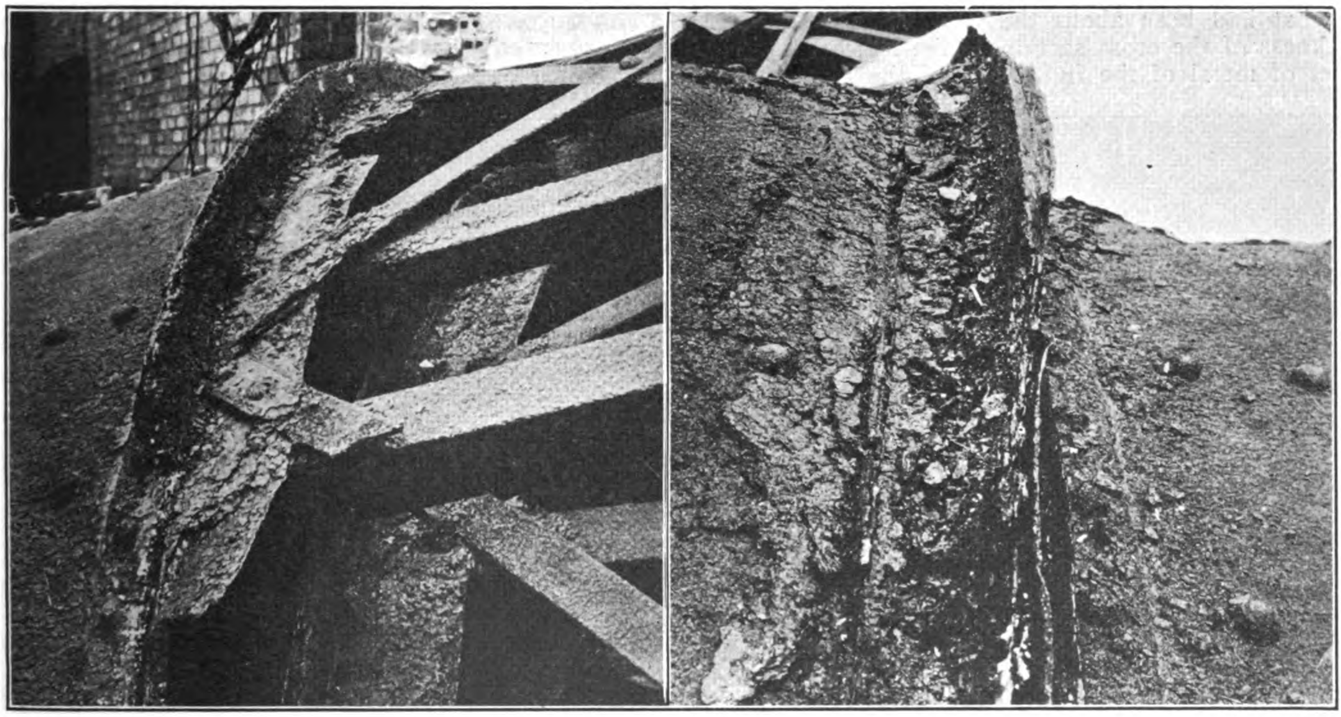
This portion of the tower framework, between and immediately adjacent to the two circular drums or girders, which weighed less than 20 tons and was not properly protected or maintained, was the only portion of the entire structural framework that was not found to be in good condition.

The circular girders or drums were about 10 ft. in diameter with 3 to 5 in. flange angles, that were presumably 3/8 or 7/16 in. thick originally. The webs of the upper and lower girders were 24 and 36 ins. deep respectively and probably about 5/16 in. thick when fabricated. The webs were found very badly corroded, deeply pitted and covered with very thick rust and scales although little of the latter had apparently been detached. Underneath the rust there was a considerable thickness of hard metal possessing enough strength and stiffness to be serviceable but to a greatly reduced degree.

The flange angles, especially their horizontal legs, were almost and in many places entirely destroyed by corrosion, large sections of a whole flange being completely gone. In general the rivets were much better preserved than either the web plates or angles, some of them being in good condition. The light latticed vertical struts connecting the upper and lower drums were very badly rusted, especially at their connections to the drums, and were nearly eaten away in places. Lattice members invite destruction when exposed.

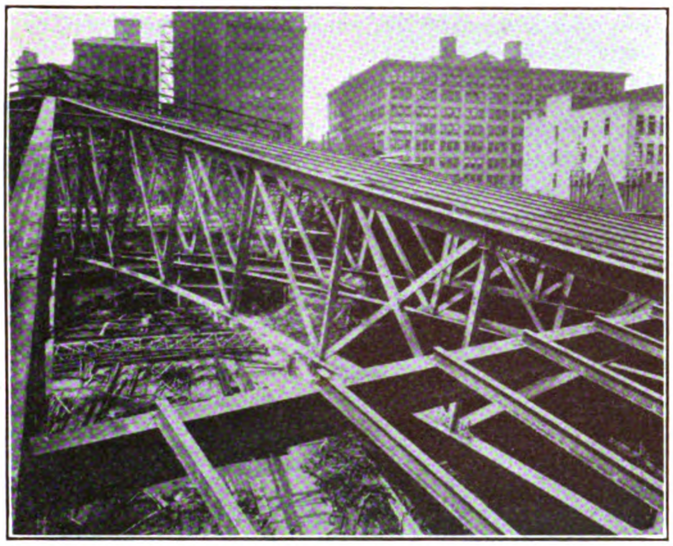
The lower drum was seated on an octangular platform made by corner plate girders 24 ins. deep riveted to the webs of the four deeper plate girders conencting the tops of the main tower columns below. All of these plate girders were badly rusted, especially the flanges of the corner girders, the horizontal legs of which were in some places corroded through their entire thickness although the disintegrated metal still remained in position, but with very little strength.

The vertical legs of the girder flange angles, although very much eaten by rust were generally in



(Left)—Lower drum of tower showing corrosion of top flange and diagonal connections of the vertical struts.. Note uninjured smooth thin sheet of metal projecting from the thick spongy, corroded laminations of outstanding leg of angle. (Right) — Extreme corrosion and destruction of sections of lower drum of upper part of tower due to exposure to moisture or electrolysis or both. The rivets were much better preserved than the web plates or angles.

better condition than the horizontal legs and had not actually crumbled away in many places. In several places the horizontal legs had entirely disappeared and in most of the other places they had become spongy and soft, swollen to several times the original thickness and peeling off in cinder like scabs and flakes, often the full width of the flange, a foot long and perhaps an eighth or quarter of an inch in thickness, a loose dirty mass that easily broke and crumbled in the fingers.



Radial roof trusses over the arena in position as exposed by the removal of the roof covering and sheathing boards. This portion of the steelwork was in excellent condition.

In all places where the horizontal legs, or portions of them, remained, the structure was changed to distinct lamination instead of hard solid metal and in many places the layers had crumbled away from the upper and lower surfaces leaving exposed in what had been about the center of the original thickness of the cross section of the leg, a very thin sheet of metal of the full width of the leg that extended to the root of the angle and apparently turned a right angle there and continued through the full width of the other or vertical leg in the center of its cross section.

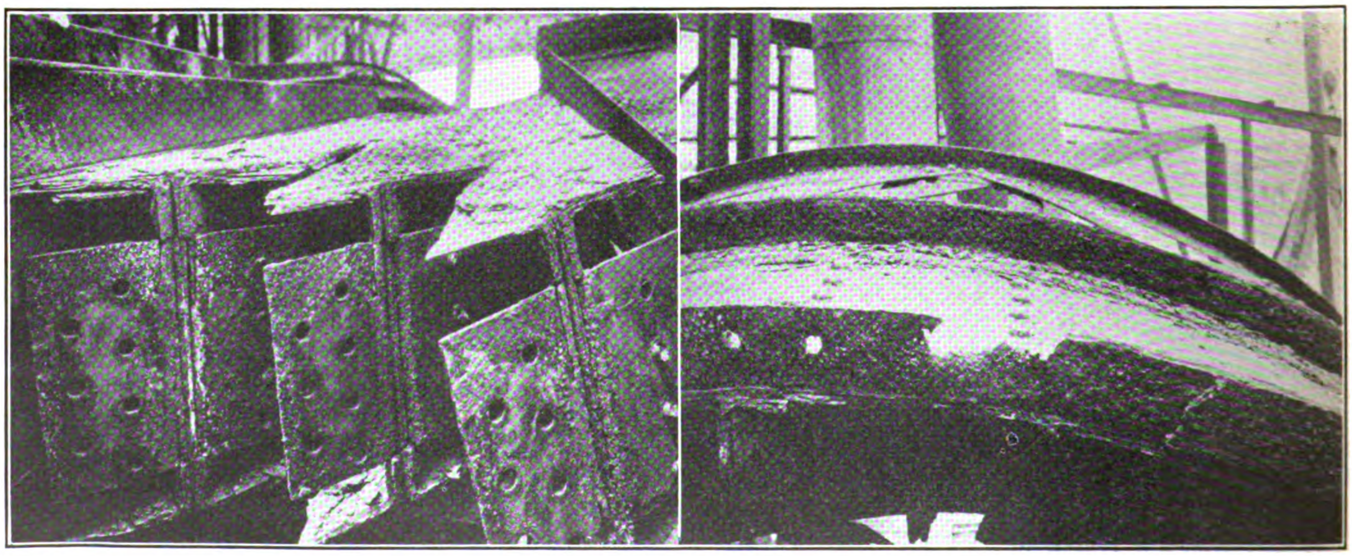
This sheet of metal was of an entirely different appearance from the material that covered it on both upper and lower surfaces when it was not fully exposed. Instead of being black, cindery looking and spongy, it was very hard, dense, strong and smooth, full width, straight-edged, without pitting or irregularities, like a good piece of sheet iron or steel of a uniform thickness of about 1/32 in. and merely discolored with yellow rust.

In some cases the upper surface of the thin central sheet was exposed and the lower surface was still covered by the spongy mass. The thin hard center sheet is very distinctly shown in several of the illustrations of girders, especially in the picture of the ends of the octagonal girders, where lamination of the spongy metal covering the center sheet on both sides is very apparent. In some cases the expansion due to corrosion and disintegration had swelled the flange to a thickness of more than 1⅛ ins.

The very definite laminations correspond with the construction of wrought iron angles which are rolled from piles of full width flat bars wired together to make a solid rectangular mass that is heated white hot and welded together into a solid bar, rolled out to the required width and thickness in flat grooves, thus continually thinning down the original flat elements to a small fraction of their original thickness.

It, therefore, seems probable that in building up the piles for these angles a different kind or quality of bar was placed in the middle, and becoming reduced by rolling to a very thin sheet, perhaps of steel, that preserved the identity and entirely resisting the corrosion that destroyed the other bars, was left practically unchanged. The action of the metal under corrosion appears to be impossible for a homogeneous uniform unit mass rolled like steel from a single cast ingot, but is consistent with the character of structural iron and the method of its manufacture.

About ten years ago, in the course of an extended



(Left)—Short corner girders in the octagonal framework supporting the lower drum of the upper tower of Madison Square Garden. Note the thin sheet of metal projecting from the corroded lamination of horizontal legs of flange angles and the definite laminations developed in both legs of the angles. The hitch angles are in good condition. The patches on them, noted in the illustration, are cement and mortar. Rivets were in excellent condition. (Right)—Top and bottom flanges of upper drum, of top portion of Madison Square Garden tower were practically destroyed by rust owing to lack of protection and proper maintenance.

study of the "Life of Iron and Steel Structures,"* the writer conferred with a large number of eminent engineers, architects and builders who expressed their opinions and outlined experiences with structural iron and steel, chiefly the latter. The conclusions reached were that although the steel frameworks of buildings are, unless properly designed, constructed and maintained, liable to possible deterioration or destruction by improper stressing, exposure or accident, good steel buildings of the present class have so far shown very little serious deterioration from any cause, and that there appears to be no reason why the life may not often be made extremely long, practically unlimited with the best design and maintenance, if exempt from fire and serious accident. In most classes of buildings the life, up to probably 100 years, is potentially limited by controllable factors, such as design, maintenance and proper use.

In the case of the Madison Square Garden the structural framework as well as the rest of the structure was well designed and built with good materials and workmanship, but no special pains whatever were taken for the protection or preservation of the iron and steel, most of which received little or no maintenance.

With the negligible exception of a portion of the tower, it was thoroughly protected from the weather but except where partly embedded in the floor construction was wholly exposed to the interior atmosphere that was well ventilated and probably free from excess of moisture or acid fumes. Escaping the exposure to fire, which it could not have long resisted, it performed for more than a third of a century all its intended functions with unimpaired efficiency, and notwithstanding lack of painting and special maintenance was as good as new when removed. By the maintenance of a watertight roof, inspection and attention, it might well have continued five or ten times as long in service under the same conditions.

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*A paper presented to the International Engineering Congress in San Francisco, September, 1915.

Protective Coatings For Metals

The Last of a Series of Educational Articles Dealing with Various Methods for Protecting Metal Surfaces Against Corrosion and Oxidation

By JAMES A. AUPPERLE*

PART III

AMONG the most successful and comparatively recent developments in the non-electrolytic process for rendering iron and steel rust resistant is the Parker Process, a modification and development of the old Coslett Process, using phosphatic iron as a protective coating. All of the older processes of rust prevention, such as the Browning, Bower-Barff and others similar in principle, though giving moderately good coatings and, in the case of the Browning method, beautifully colored and lasting finishes, were uneconomical of time expenditure of heat, and in some cases required a multiplicity of operations. The personal skill and experience of the operator were also most important factors in many of these processes where high temperatures, muffles and combinations of fused salts were used.

Phosphatic treatment to make iron and steel rust resisting differs from other methods in that the dimensions or sharpness of finely machined edges and surfaces of the articles are not appreciably altered. Due to the low temperatures used, the physical properties of tempered steel are in no way affected, and magnets so treated retain their magnetic force. Even very fine springs do not have their elasticity impaired. Dental needles having points so fine (0.003 in.) that a slight corrosion ruins them completely are successfully protected by phosphatic coatings without injuring the elasticity of the needles or affecting the delicate barbs covering ther surfaces.

Parkerizing is effected simply by immersion of the clean objects in a hot saturated solution of manganese and iron phosphates for periods of one to two hours. The deposition of the phosphatic coating depends on the action of a saturated solution of acid, iron and manganese phosphates on a metallic base, such as iron. During the period of immersion, these phosphates will be precipitated on the surface of the objects treated. What actually happens is that a certain amount of the metal is removed as ferrous phosphate and the iron-manganese phosphate combination is deposited in its place. This substitution explains the fact that dimensions of Parkerized objects do not change after processing.

Parkerizing produces more resistant and uniform coatings than the old Coslett method as the precipitated phosphates are really a mixture of ferri-ferrosso and mangano-manganic instead of ferrous phosphate alone as produced by Coslettizing. Oxygen is introduced in the Parker Process so as to establish the correct proportion between the ferrous and ferric phosphates, which combination is most resistant to rust.

Nature of Coating.

The phosphatic crystallization on iron and steel articles after removal from the Parkerizing bath is of uniform dark gray color, varying in intensity of shade according to the surfacing treatment the article has previously received. In common with all methods for metal coloring the shadings obtained with the phosphatic coatings are dependent largely on the preliminary cleaning methods, such as sand blasting, pickling, tumbling, rubbing, buffing, etc.

It is interesting to note that while the phosphatic coating is crystalline in structure, there is a remarkable adhesion or molecular bonding to the metal itself. This is best shown by the considerable distortion the treated parts will stand, the coatings remaining even, and uniform without evidence of rupture or cracking. The color imparted to iron and steel by Parkerizing is a very dark gray, differing somewhat from the lighter shades obtained by Coslettizing. This is due to the partially oxidized manganese and iron phosphates.

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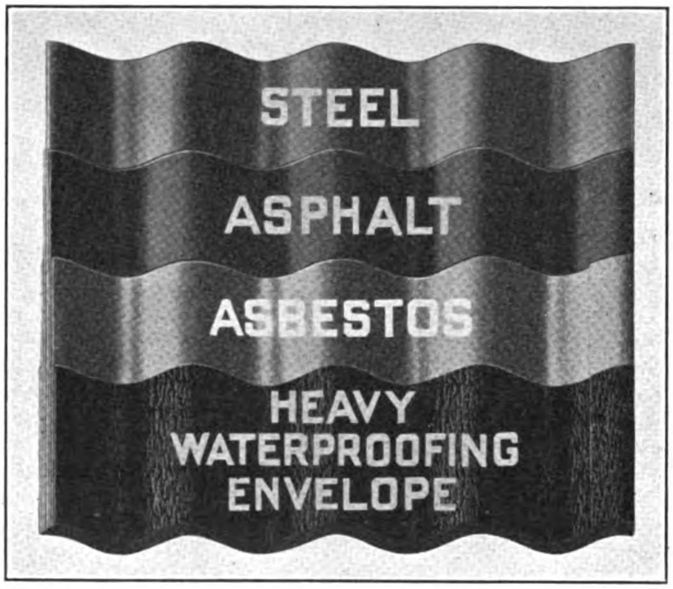
*Middletown, Ohio.

The Parkerizing bath can be modified, permitting the formation of coarser and heavier crystallizations, these being particularly well adapted as a base for enamels and paints on structural iron work. The coarser crystallizations can be most successfully used in combination with bituminous enamels.

Parkerizing shows no added deposit or layers such as are produced on steel treated by hot or electric galvanizing. In fact, in these processes certain allowances must be made on threaded parts to compensate for the thickness of zinc used. Heavy castings of intricate shape, containing irregular cavities, can be completely Parkerized as the phosphates will form on all parts immersed in the rust-proofing bath. Light castings, stamping and screw machine products can be easily and economically handled in bulk as no stringing or racking is necessary as in plating.



Asbestos Protected Metal

The handling problem, therefore, is greatly simplified. Its advantages need no description when compared with the piece handling which is current practice in hot-galvanizing methods. Another interesting point is that when iron and steel parts are Parkerized, the phosphatic coatings cover the entire piece even at points where contact marks should be expected. A good illustration of this is the processing of medium sized bolts and nuts, which are dumped into a suitable mesh basket after cleaning; this basket holds about 800 to 900 pounds. The entire load is then immersed in the processing bath and a careful examination of the processed work will show a uniform phosphatic covering on each and every piece.

Another very large field for Parkerizing is its use as a base for paints and enamels. The process leaves the metal treated with a dull mat-black surface. This makes a priming coat unnecessary and many manufacturers are putting on a finish gloss enamel for the first and final coat with excellent results. Where the highest grade enameling is required, two coats of enamel over the Parkerizing will produce a very high grade finish. The enamel is bonded to the metal and may be subjected to considerable abuse without peeling or chipping. Furthermore, should the paint be removed by abrasion, the surface underneath would still be protected and the spreading of rust so frequently occurring on enameled steel prevented. The phosphate surfacings are in no way affected by the heat of the enameling operation.

The Parker Process is finding increasing use and can be considered an important advance in metal protection since galvanizing was first introduced. Due to the fact that the process does not affect the dimensions, weight, temper, elasticity, magnetic qualities or conductivity of the parts treated, it can be used in many places where other protective processes fail. All grades of iron and steel, malleable castings, forgings, screw machine products, stampings, whether large or small size, can be treated with equal success. The process is applicable to finely finished machine parts where close limits must be maintained. Some of the most successful applications are: Automotive Equipment, Electrical Equipment, Canning Machinery, Textile Machinery, Typewriter and Adding Machine Parts, Light Weight Structural Iron, Scientific Equipment, Aeroplane Equipment, Locks and Chains, Tools, Stoves, Machinery, etc.

Parkerizing is done in a steel tank, the side heating coils being provided with deflection vanes to induce continuous circulation of the solution. Any sludge or precipitation which may occur during processing is prevented from coming in contact with the work by baffle plates, placed a certain distance from the bottom of the tank. The articles to be processed are immersed in the bath for periods varying from one to two hours at approximately 210 deg. F. When the evolution of hydrogen from the work ceases, this is an indication that the phosphatic reaction has been completed and the work can be removed. Insofar as the chemical action of the bath automatically stops, the chances of error in processing are practically eliminated. The phosphated steel is then ready for impregnation with a light mineral oil which converts the gray color of the processing to a soft mat black appearance when dry. Recent developments now make it possible to produce steel in a great variety of finishes. These vary in lustre and in resistance to abuse.

Parkerizing is the cheapest method of making iron and steel rust resisting known today. Ease of handling, simplicity of treatment and uniformity of results are important factors in its favor.

Articles on which it is desired to have a coating of black magnetic oxide of iron are heated in closed retorts at a high temperature after which superheated steam is injected which forms a coating of black magnetic oxide. Such coatings are said to resist acid fumes in a satisfactory manner and are not affected by solutions of copper sulphate. In a modification of the process, steam and carbon monoxide are introduced into the retort at the same time. This treatment also produces magnetic oxide of iron.

Articles treated by the Bower-Barff process carry a very brittle coating and one which is very easily damaged, and if the base metal is exposed, rusting will result and finally work under the coating causing it to peel. The coating on articles treated by the Bower-Barff process if strained beyond the elastic limit will scale off.

Articles can be heated to 40 deg. F. and immersed in cold water without injuring the coating. Such coatings are said to resist the action of sea air, sea water, alkaline and organic acids and also the caustic action of lime and hydraulic cement. They are easily removed, however, by the action of either hydrochloric or sulphuric acids. Frederick S. Barff was the original inventor of this method of coating while later improvements were made by Messrs. George and Anthony Bower.

The cost of treating articles by this process is estimated at about 5 per cent of the net cost of the articles to the manufacturer. This includes builders' hardware and the class of articles called shelf goods. Wrought iron grilling, office railings, and the better class of scroll and fancy work cost about two cents a pound to treat by this process. Wrought iron beams, channels, and other shapes entering into building construction can be treated at a fraction of a cent a pound.

Asbestos Protected Metal.

Asbestos Protected Metal is the name applied to a process by which the corrosion of the steel core is lessened by protective coatings of (1) asphalt, (2) asphalt impregnated asbestos felt and (3) waterproofing. In effect it is a combination of corrugated steel roofing with roll roofing applied to both sides of the sheets.

Originally asbestos protected metal consisted simply of a steel sheet protected by one coating of asphalt and asbestos felt, but for the past seven years it has been made in the form described.

The material is chiefly used for industrial roofing and siding, for building trim and for fume ducts, though skylight bars and ventilators are also protected by the same process.

The steel core sheets are cleansed and are then passed through a bath of asphalt heated to a uniform and definite temperature. Following this bath they are enveloped in asbestos felt that has previously been saturated with asphalt. The felt is turned over both edges of the sheets, is sealed at the ends and passed between powerful rolls that bond the felt and the first asphaltic coat.

The sheets are then allowed to cool before passing through the final waterproofing coating. The waterproofing has a pure asphaltic base from which the oils have been distilled, resulting in a strong, tough, rubber-like material that is not affected by the rays of the sun, from which it protects the first two coatings. After the waterproofing coating is in place, the sheets are corrugated, or formed in any other manner that may be specified for structural use.

The finished sheets have all the strength, light weight and adaptability of corrugated steel combined with the durability of built-up roofing, without its need for a wooden deck. Its insulating qualities are equal to those of a ⅞-inch pine plank, which is a material where condensation must be considered. The thermal conductivity of asbestos protected metal 0.11 inch thick is approximately .9 Btu. per square foot per deg. F. per hour, while that of black or galvanized sheets is 2.13 Btu. per hour.

The natural color of the material is black, though it is also made in maroon and with aluminum finish. Where coatings of other colors are desired, care must be exercised. For interior decorative effects fairly satisfactory results are obtained by applying a priming coat of shellac and then applying a watercolor paint or a drying oil paint. Ordinary paints applied to the asphaltic surface will crack or discolor.

The material can be applied at any time of the year in any climate, but it is not suitable for use on buildings where the heat is continuously above 140 deg. F.

Asbestos protected metal at first was used around pickling plants, fertilizer and chemical plants, ocean piers, smelters and other places where extremely corrosive conditions are found, but because of its resistance to less severe conditions and its freedom from painting and maintenance expense it is used generally where corrugated building materials are required.

Paint Coatings—Red Paint.

Space will not permit a discussion of all the various kinds of paints used for protective purposes. I have had under my supervision many different types of paints and have come to the conclusion that a red iron oxide paint, containing a small amount of red lead and asbestine, gives the best results. Oxide of iron is one of the best pigments for lasting power, remaining practically unchanged after years of exposure. Red paint of the following composition has been found to give excellent results.

Volatile Thinner	8.5 per cent
Linseed Oil	21.5 per cent
Iron Oxide	52.5 per cent
Red Lead	10.1 per cent
Asbestine	7.2 per cent

Black Paint.

A most excellent black paint for iron and steel can be made for less than 50 cents a gallon and will afford almost as much protection as red iron oxide paint. This paint consists of ordinary gas house coal tar which is mixed with 10 per cent to 20 per cent dry Portland cement, and thinned with benzol if necessary. It can be applied with a spraying machine and should be kept agitated in order to keep the cement in suspension. The cement has the property of combining with the acids and water always present in coal tar and of producing harmless compounds in the paint. This paint can be used on metal buildings, and is an excellent coating for smoke stacks as the cement forms an egg sheel coating after the coal tar is destroyed. It should not be used on sheets which are to be piled as it requires at least one week's time to dry.

Both the black and red paints have been given thorough tests at the sea shore and at many inland cities with very satisfactory results under all kinds of conditions.

Vitreous Enameled Sheets.

Up to the present time very little has been done in the way of producing a vitreous enameled sheet for its resistance to corrosion where the conditions are unusually severe. Great progress has been made in recent years in the enameling industry as most of the modern plants employ scientifically trained men to keep a check on the process of manufacture.

The base of vitreous enamel is clay to which various other substances are added in order to lower the melting point of the product. The process is adaptable to the manufacture of various colors and various types of vitreous enameled coatings, some of which are especially designed to resist the action of acids.

Experiments are now being conducted on vitreous enameled corrugated sheets which have been coated with one and two coatings of vitreous enamel. These sheets are being tested in comparison with uncoated

(Continued on page 357)

Selection of Coals for Coke Manufacture*

A Discussion of Physical and Chemical Characteristics of Coal for the Manufacture of Blast Furnace, Foundry, and Water-Gas Coke in By-Product Ovens

By H. J. ROSE†

SIXTY-FIVE million net tons of coal were carbonized in the by-product and beehive coke ovens‡ of the United States during 1924. This tonnage represented 13.4 per cent of the bituminous coal which was mined in that year. Table I shows production and disposition.§

TABLE I—Production and Disposition of Oven Coke in 1924

	By-product	Beehive	Total
Coal charged into ovens, tons..	49,061,339	15,914,310	64,975,649
Coke produced (exclusive of screenings and breeze), tons..	33,983,568	10,286,037	44,269,605
Average yield of coke, per cent	69.3	64.6	68.1
Disposition of coke:			
	%	%	%
Blast furnace	82.5	82.8	82.6
Foundry	4.6	13.3	6.6
Domestic	8.3	1.4	6.7
Water gas manufactured and all other uses	4.6	2.5	4.1

Cokes having somewhat different combinations of chemical and physical properties are desired for the various uses listed above, and these properties depend primarily upon the types of coal used. American coals have a wide range of purity and coking quality, and the chief subject of this paper will be the selection of coals for the manufacture of blast furnace, foundry, domestic, and water-gas coke, in by-product coke ovens. It will obviously be necessary to include a discussion of those physical and chemical characteristics that are generally considered essential or desirable for each type of coke.

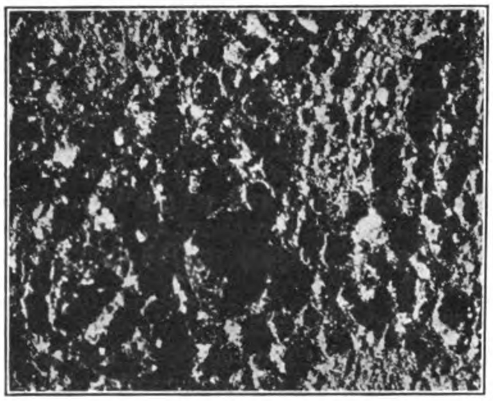


FIG. 1—Cell structure of by-product coke made from 34 per cent volatile matter high-oxygen coal, No. 6 Seam, Franklyn County, Ill. x25.

Suitable Coals—The examination and development of new sources of coking coal are important because of the irregular and limited distribution of high-grade coals of established coking quality, and the rapid rate at which our reserves of such coals are being depleted for various purposes. Great advances in the design and construction of by-product coke ovens have recently made possible the use of coals which were hitherto considered unsuitable for coking. Therefore, a description of several methods for determining the quality of coke that can be produced from a given coal, is appropriate, also a brief discussion of the relations between the chemical composition and coking properties of coal. The characteristic behavior of certain coals when heated, which makes them amenable to coking, will first be described.

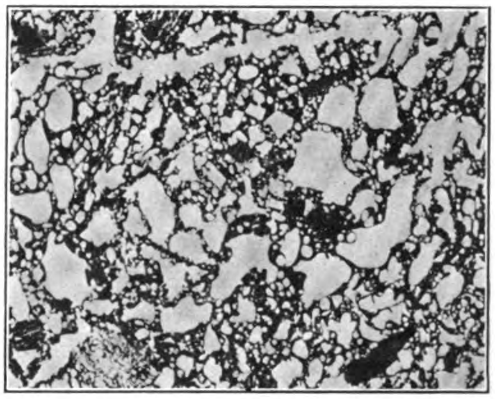


FIG. 2—Cell structure of bee-hive coke from 34 per cent volatile matter washed coal, Las Animas County, Colo. Cells are filled with white composition and only the cell walls are visible. x4.

Behavior of Coking Coals When Heated.

Coke is the coherent cellular residue from the destructive distillation of certain bituminous coals. When a small sample of such a coal is heated at a uniformly increasing temperature in the absence of air, it will exhibit a definite fusing or softening temperature, usually occurring between 300 deg. and 400 deg. C., and will become pasty or semifluid. Gases of decomposition begin to appear in appreciable quantities at the fusing temperature, or slightly higher, and are soon evolved copiously, causing the mass to become cellular and more or less swollen. The viscosity of the fused and pasty coal rapidly increases as decomposition proceeds, and the hot mass becomes substantially rigid before a temperature of 450 deg. C. is reached. However, it is continually subject to further changes in structure due to devolatilization and shrinkage, and these changes are still in evidence after the coke has reached a red heat. Gas evolution continues at a rapid rate long after the initial rigidity has been attained.

Such in brief, is the behavior of all good coking coals when heated. Poorly coking coals react similarly in a varying but less degree, and the temperatures of initial gas evolution very considerably. In

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*A paper presented at the July 1926 meetings of the American Institute of Mining and Metallurgical Engineers.

†Assistant Chief chemist, The Koppers Company, Pittsburgh, Pa.

‡About 5,000,000 additional tons of coal were carbonized in gas retorts.

§Adapted from U. S. Bureau of Mines report No. 245, Sept. 5, 1925.

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fact, the typical cellular structure of coke* is caused by the evolution of gas bubbles in a mass of fused coal that is stiffening through thermal decomposition. (Figs. 1 and 2.) Non-coking coals do not fuse and become pasty under the influence of heat.

Coke Formation in a By-Product Oven.

We have been considering the case of a small sample of coal heated at a uniformly increasing temperature, but when coking coal is charged into a red-hot chamber, the resulting conditions are considerably more complex. In the by-product coke oven, the coal which comes into contact with the hot walls is rapidly carbonized, and a narrow pasty layer called the "plastic zone," or "pitchy seam," is formed parallel to each heating wall. As carbonization proceeds, these layers move towards the center of the oven at an average rate of about 0.5 to 0.65 inch per hour. The plastic zones consist of fused coal with tarry or pitchy material from coal that is being distilled. The thickness and nature of these zones depend on the kind of coal used, the degree of pulverizaton, rate of coking, etc. With good coking coals, especially when they have been well crushed or pulverized, there can be little doubt that the plastic zones are substantially impermeable to gases during most of the coking period.

There is a sharp temperature gradient in the vicinity of these zones. Most of the gases and vapors are liberated on the hot side of the plastic zone and in the adjacent low-temperature coke, and are forced by their own pressure towards the oven walls, where they stream upwards, either along the walls or through shrinkage cracks in the coke. The rich gases are cracked to some extent by contact with hot surfaces, and they accordingly deposit on the coke a silvery carbon or hydrocarbon film often referred to as a graphitic carbon deposit.

To show the progressive nature of coke formation, three boxes of coal were charged at intervals into an otherwise empty coke oven, and were discharged together before the plastic seam had quite reached the center of the box charged first (shown at the left in Fig. 3.) The boxes were immediately quenched, the tops cut away, and the upper layers of coke removed to show the progress of coking.

When the coking process is well under way, a variety of solid products exist in the oven. Adjacent to the walls there is a layer of high-temperature coke which has already begun to shrink and fracture somewhat from the intense heat, and which is acquiring a silvery surface deposit. This high-temperature coke is continuous with, and grades imperceptibly into lower and still lower temperature coke, until the plastic zone is reached. The plastic zone is usually ¾ to ¼ inch thick, and on the hot side is cellular and merges rather indistinctly into low-temperature coke. The cool side of the plastic zone, where the coal is just starting to fuse, is very sharply defined. Individual fragments of coal on the border line are seen to be fused at one end, and little changed at the other end. The coal in the interior of the oven and shielded by the plastic zones, remains unchanged and at a temperature little above that of boiling water for many hours, until it is finally reached by the slowly moving pasty layers. In actual practice, coking is usually continued not only until the plastic zones have met, but until the coke at the center of the oven has attained a red heat. A division line is present where the two plastic zones have come together, and the coke mass breaks apart along this plane, so that individual coke pieces are but half as long as the oven width.

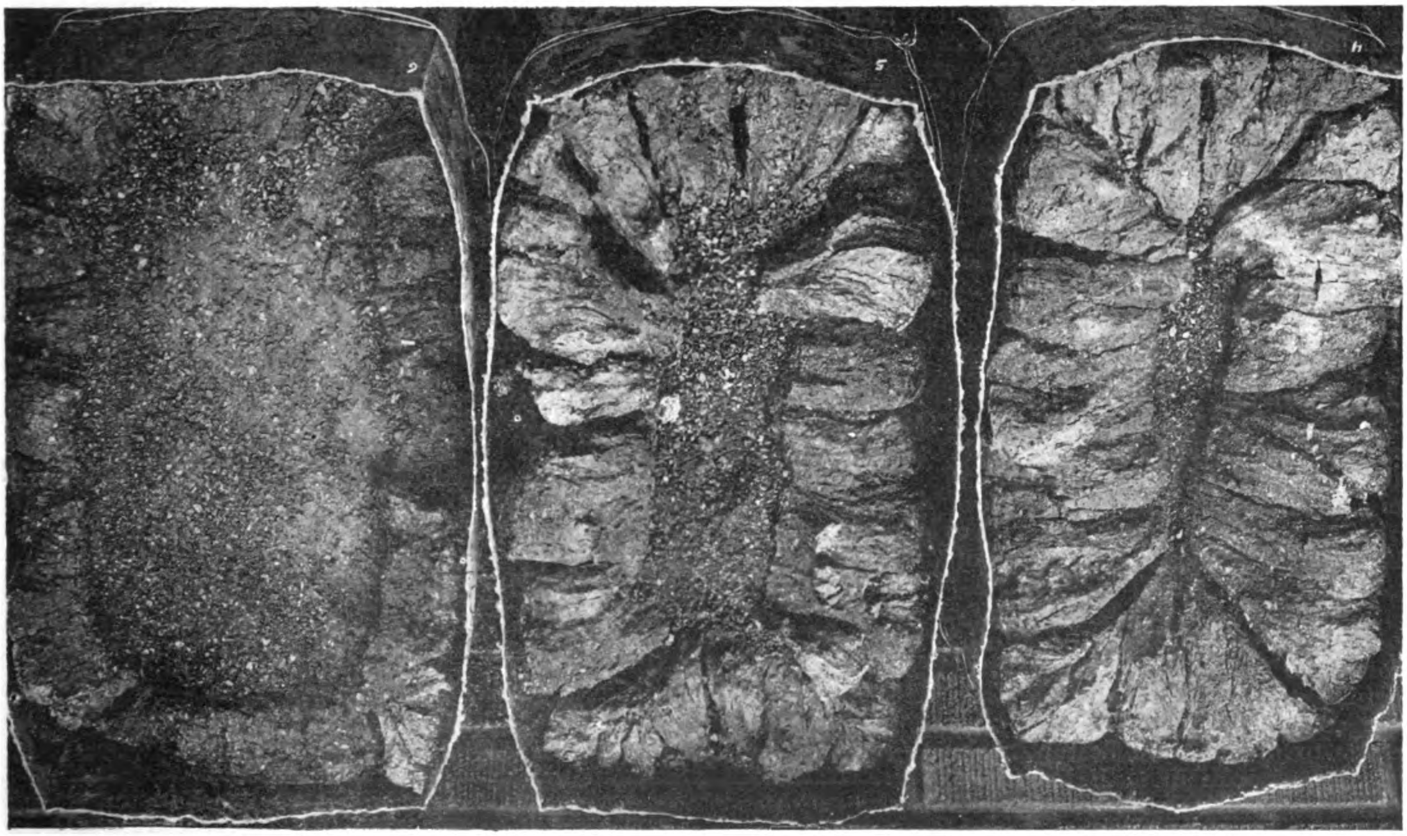

FIG. 3—Box tests made in empty coke oven to show the progressive nature of coke formation.

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*H. J. Rose, "The Study of Coke Macrostructure." Ind. and Eng. Chem., 17 (1925), p. 895.

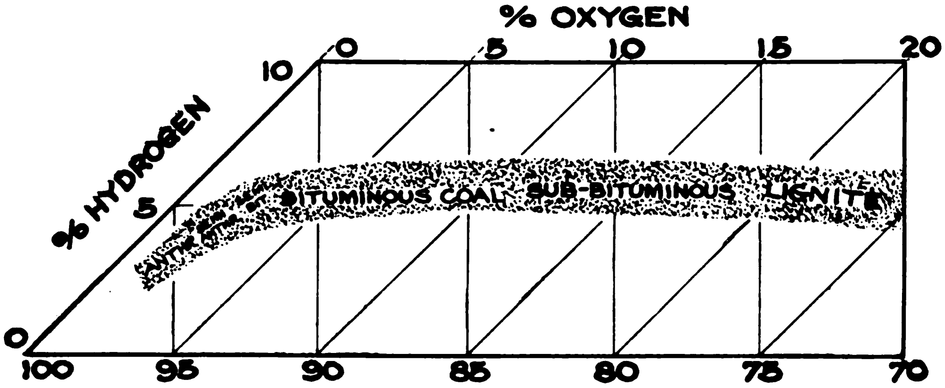

FIG. 4—Tri-axial diagram of ultimate analyses of coals.

Definition of Coking Coal.

The commercial value of coke depends upon its purity, and upon such factors as size, strength and structure. These physical characteristics are determined not only by the kind of coal used, but also by the degree of pulverization and moisture content of the coal, the amount, nature and size of impurities such as slate, the temperature of the oven walls, dimensions of the oven and other variables, all of which affect the coke at some stage of its formation. Therefore, it is not surprising to find that the only thoroughly reliable way to determine the quality of coke that can be made from a coal under particular conditions, is to subject the coal to a full-scale oven test under the desired conditions.

For practical purposes, a coal may be classed as a coking coal if it will yield a merchantable coke when carbonized by a commercial method in an existing type of coke oven. In order to be merchantable, a coke must, in general, be of adequate purity, size, strength and structure, for the uses to which it is to be put. Furthermore, the coke from any coal or coal mixture carbonized in by-product ovens must be strong enough, and have sufficient shrinkage from the walls, to permit its discharge from the ovens without difficulty. Coal mixtures are commonly used at by-product coke-oven plants, and this practice has resulted not only in the production of superior coke, but in the extensive utilization of coals which would not be very suitable for coke manufacture, if used unmixed.

Determination of the Coking Properties of Coal.

The problem of determining the coking quality of coal by test methods has received an amount of attention warranted by the great industrial importance of coke. It will not be practical to mention in detail the many methods that may be used as an aid to determining coking properties, but a few of the preferred methods will be briefly discussed, and their scope of usefulness indicated.

Oven Coking-tests—It has already been stated that full-scale oven tests form the only accurate and thoroughly reliable means of evaluating the coking properties of coal. In order to produce the best possible quality of coke in such tests, the condition of the coal as charged and plant operating conditions must often be varied. For these reasons, and because of the expense involved in such tests, it is important that they be carried out under competent direction, to obtain the best possible coke with the minimum number of tests. For a single charge in a full-sized by-product coke oven of the most modern type, 11 to 15 tons of coal are required, and as more than a single test is usually desirable, a carload of coal is the minimum quantity recommended for such a test.

Box Coking-tests—If coking quality of coals is doubtful or if it is suspected that the coke formed will not shrink sufficiently to permit ready pushing from the oven, it is advisable to make preliminary test by embedding a specially designed metal box of the coal in a regular oven coal-charge. If the results are definitely unfavorable, the expense of a full-scale oven test is thus eleminated and possible interference with plant operation avoided. Box tests are also recommended when but little coal is available. (Fig. 3.)

When properly made box tests are of considerable value, and give to the experienced observer a definite idea of the character and coking possibilities of the coal tested. They cannot take the place of full oven tests when an accurate determination of the physical properties of the coke is required. Very erroneous ideas may be obtained from incorrectly made box tests.

Laboratory Coking Tests—Sometimes an approximate determination of the coking properties of a very small sample of coal must be made, for example, on part of a coal core from diamond drilling. An appartus* devised by F. W. Sperr, Jr., permits a fairly satisfactory determination to be made on a sample of about 2 oz. placed in a tube of such diameter that the coal occupies a length equal to half the width of a coke oven. Coking is begun at one end of the coal by means of a previously heated furnace, and the coal and furnace are moved with respect to each other at such a rate that the rate of progression of heat into a coke-oven charge is duplicated. An ingenious arrangement permits shrinkage or expansion under any desired load to be measured continuously throughout the test. Much interesting and valuable information has been obtained with this apparatus.

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*U. S. Patent No. 1444567.

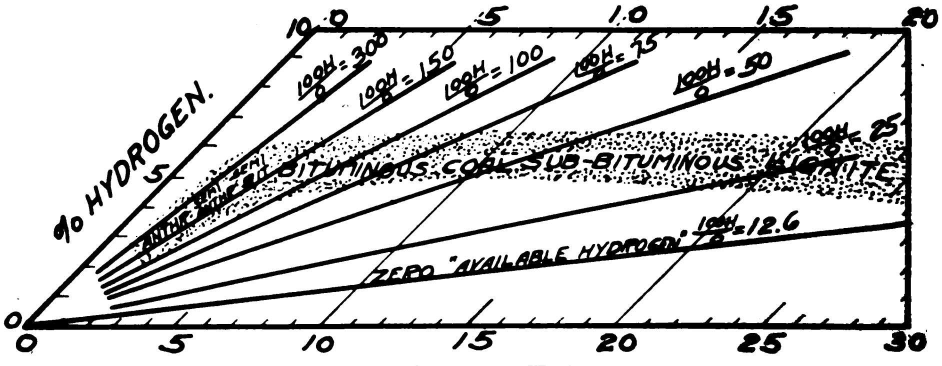

FIG. 5—Hydrogen: oxygen ratios, tri-axial diagram.

The simplest of all coking tests is no doubt the standard volatile-matter determination in which a gram of powdered coal is suddenly heated to redness in a small platinum crucible. The resulting coke button will indicate whether the coal is non-coking, feebly coking or strongly coking, but almost every condition in this test is at variance with large-scale carbonizing practice.

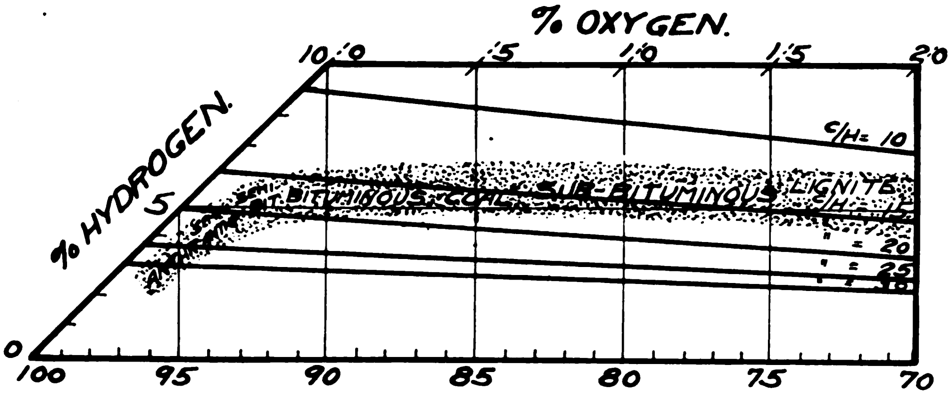

FIG. 7—Carbon: oxygen ratios, tri-axial diagram.

Over a period of many years all of the above types of coking test have proved to be useful, full-scale oven tests being invariably used whenever practicable. Many other tests have been proposed and used by coal investigators, some of which have undoubted merit for their respective purposes. One such test, which with numerous variations is often used abroad, consists in mixing a definite weight of coal with successive and increasing proportions of carefully sized sand or carbon particles. In a typical test of this sort, the ratio of sand to coal in that mixture which, when coked, will just support a stated load without crushing and without forming more than a specified amount of fines, is taken as the coking index or sand-test number.

Correlation of the Chemical Composition and Coking Properties of Coal.

The question "Can the coking properties of coal be predicted by chemical analyses?" is frequently asked. In spite of the many studies which have been made of coking coals, an affirmative answer cannot be given without reservations.

Use of Ultimate Analyses—The writer has made a graphic study* of the ultimate analyses of many hundreds of American and foreign coking coals, and has been particularly fortunate in having available the by-product yields for a large number of these coals, together with scores of very complete records of by-product oven coking tests. All coking coals appear to fall within fairly definite chemical limits, so far as their ultimate analyses are concerned, and it is the writer's experience that from the location of a coal within these limits, the coking properties and by-product yields may be predicted with reasonable accuracy, if all essential data on the chemical and physical characteristics of the coal as it will be charged, and the operating conditions which will exist, are known. Coke quality and by-product yields are greatly affected by many chemical and physical variables, and by operating conditions, and while the influence of each of these independent variables is more or less well understood, the difficulty of evaluating the effect of complex combinations can easily be appreciated. Experience indicates that such a task should be left to specialists who have had ample practical experience in testing a wide variety of coals.

The most rational scheme of studying coals according to their ultimate analyses is undoubtedly the use of trilinear co-ordinates, as proposed by Grout* nearly 20 years ago, and as amplified by Ralston† some 10 years ago. For this graphic method the ultimate analyses must be reduced to three variables which always total a constant amount. One method is to calculate the analyses free of moisture, ash, sulphur, and nitrogen, so that the sum of the remaining carbon, hydrogen and oxygen will always total 100 per cent, but obviously two or more items can be combined in any of the three variables. If a right-angled triangle is used as the basis of the co-ordinate system, then ordinary rectangular co-ordinate paper can be used by expressing two of the variables with the existing lines and by drawing in diagonal lines to express the third. Of course the third variable need not be indicated at all, as its numerical value can always be obtained by subtracting the sum of the other two variables from 100 per cent.

Seyler's Classification—Such a system would be the graphical equivalent of the coal classification proposed by Seyler‡ in 1900. Seyler, using ultimate analyses calculated free from ash and sulphur, divides coals into named groups by means of limit percentages of carbon and hydrogen so selected that the coals in each group possess certain resemblances. This classification is used by British fuel investigators, and apparently agrees rather well with several graphic classifications of American coals.

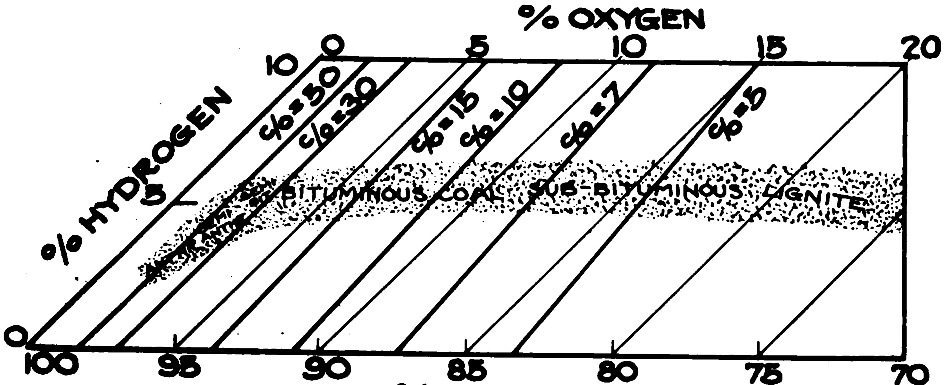

FIG. 6—Carbon: hydrogen ratios, tri-axial diagram.

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*H. J. Rose, "Graphic Study of Coking Coals. (Unpublished.) Presented before the Gas and Fuel Section of the American Chemical Society, Washington, D. C. April 25, 1924.

*F. F. Grout, "The Composition of Coals." Econ. Geol., 2 (1907), 225-241.

†O. C. Ralston, "Graphic Studies of Ultimate Analyses of Coals." Tech. Paper 93, U. S. Bureau of Mines (1915).

‡C. A. Seyler, Proc. South Wales Inst. Eng., 21 (1900), 483 et seq.; also The Chemical Classification of Coal, Fuel in Science and Practice, 3 (1924), 15-26, 41-49. 79-83.

Use of Ratios—When the ultimate analyses of solid fuels are plotted on triangular co-ordinates, the analyses of wood, peat and all coals ranging from lignite to anthracite (cannel and alga coals being excepted) fall within a remarkably narrow band in one corner of the triangle. Fig. 4 (adapted from Ralston's paper) shows part of this band on which the location of the various ranks of coal are indicated. The stippling on this figure does not represent actual coal analyses, but simply indicates the limits within which most coal analyses will fall. The bituminous and semi-bituminous classes consist chiefly of coking coals.

Many investigators have attempted to classify coals by the use of certain ratios such as Hydrogen: Oxygen, $\text{Hydrogen} - \frac{\text{Oxygen}}{8}$, Carbon: Hydrogen, and Carbon: Oxygen. To understand what these ratios mean when applied to coal is rather difficult. Figs. 5, 6 and 7 will help to illustrate their probable usefulness, also the obvious limitations of such ratios.

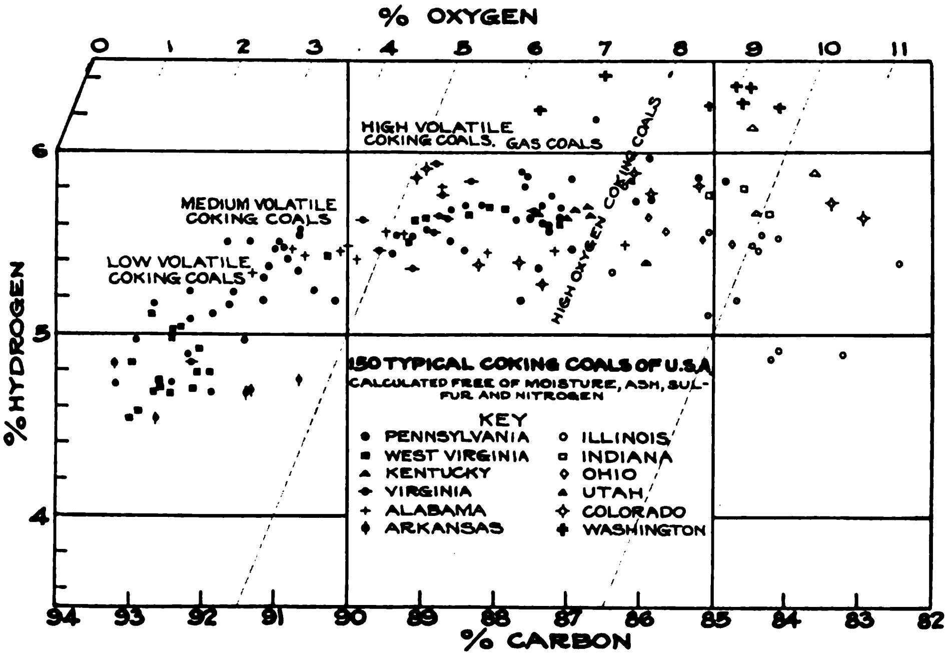

FIG. 8—Diagram of the ultimate analyses of 150 coking coals of the United States.

Detailed discussion of these figures is beyond the scope of this paper, but it should be pointed out that owing to the sharp curvature in the band of coal analyses occurring at about 92 per cent carbon, 5 per cent hydrogen, and 3 per cent oxygen, no linear equation can be adequate over the whole range of coals.

Hydrogen: Oxygen Ratio—Thus in Fig. 5, the lower H:O ratios cut across the band of lignite, sub-bituminous and bituminous coals (though much more obliquely than the oxygen lines), but for the coals of higher rank, the ratio lines run parallel with the coal band. Thus, a single H:O ratio line may pass through as many as four ranks of coal (as well as cannel coals, which are not shown but would fall above the bituminous coals). The H:O ratio is particularly well known because of White's frequently quoted conclusions* on the limits of this ratio for coals that can be coked in beehive ovens. White pointed out that the relation between H:O ratio and coking quality was subject to exceptions for the coals of lower volatile-matter content.

Fig. 5 also permits the graphic estimation of the "available hydrogen" in coal, that is, the percentage of hydrogen in excess of that which would be required to combine with all of the oxygen present to form water. This index has long been known but is generally considered to be of doubtful reliability.

Carbon: Hydrogen Ratio—Fig. 6 shows that the C:H ratio lines are not very different in slope than the hydrogen lines, and apparently for most purposes the hydrogen percentage in pure coal would be just as satisfactory an index, and one simpler to use and understand. The C:H ratio has been chiefly used in districts where anthracite, semi-anthracite and semi-bituminous coals are produced, for which coals this ratio serves as a means of differentiation just as the hydrogen percentage would. For coals of lower ranks the ratio would appear to have a very limited use, as it does not distinguish between coals of widely different rank.

Carbon: Oxygen Ratio — Fig. 7 shows that the slope of C:O ratio lines is so nearly the same as that of the oxygen lines that the use of the oxygen percentage in pure coal would probably be just as satisfactory for most purposes.

The application of other ratios, such as $\frac{\text{Volatile carbon}}{\text{Carbon}}$, $\frac{\text{Fixed Carbon}}{\text{Volatile matter}}$, are subject to well known limitations which need not be discussed here. A study of the shortcomings of the various ratios and indexes which have been proposed from time to time, indicates that it is not possible to classify coals adequately by means of single index numbers, but that a two-dimensional system or diagram is necessary. If ultimate analyses are to be used as the basis of classification, systems such as those of Ralston and Seyler are indicated as the most logical.

Tri-axial Diagram of Coking Coals of the United States—Fig. 8 represents the ultimate analyses of about 150 coals from 10 different States. They have been classed as "typical" coking coals in the sense that they represent a wide geographical distribution and range of chemical composition. Most of these coals have been used for by-product coking, either alone or in mixture with other coals. By combining Parr's "unit coal" correction* for ash and sulphur with the nitrogen content, the original ultimate analyses have been recalculated to the basis of Carbon + Hydrogen + Oxygen = 100 per cent. It should be noted that the vertical or hydrogen percentage scale of this chart has been expanded two and one-half times with respect to the horizontal or carbon percentage scale, in order to permit all points to be distinctly plotted. If the same scale had been used for both components, the band of analyses would have been correspondingly narrowed and more sharply defined.

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*D. White, "The Effect of Oxygen in Coal," Bull. 29, U. S. Bureau of Mines (1911), or U. S. Geol. Survey Bull. 382.

*S. W. Parr, "The Classification of Coal." Jnl. Ind. and Eng. Chem., 14 (1922), 919.

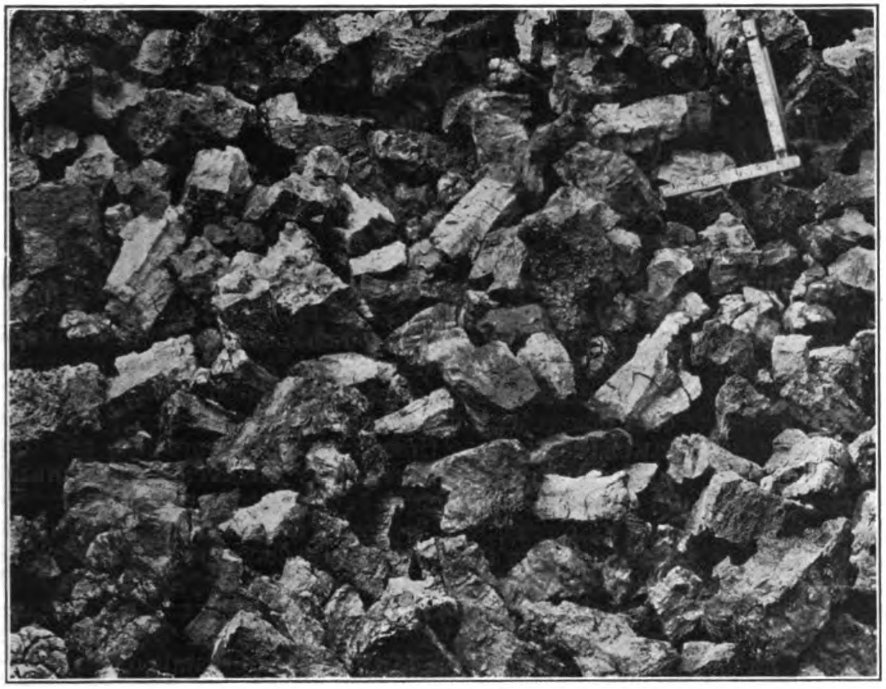

FIG. 9—Low-volatile coal coked in 14-in. Becker oven. Run-of-oven coke on wharf, made from 21.1 per cent volatile-matter coal mined in Pierce County, Washington. This coke was easily discharged from the oven. Net coking time, 11 hr. 47 min.

Classification of Coal by Volatile Matter Content.

The terms low, medium, and high-volatile coking coals, gas coals, and high-oxygen coking coals, which are used on Fig. 8, do not designate sharply defined classes. These and similar terms are used by by-product coke-oven operators in a relative sense, and the exact meanings intended by the individual operator may vary somewhat with the nature of the coals with which he is best acquainted, or which are available for his plant.

Low-volatile Coking Coal—In the northeastern quarter of the United States (where more than 80 per cent of the by-product coke is produced), the term "low-volatile coal" is used chiefly to designate coals of less than 20 per cent volatile matter such as the Pocahontas and New River, W. Va., and Somerset County, Pa., type. For by-product oven use, such coals are mixed with high-volatile coking or gas coals in any proportion up to 60 per cent or more (but usually from 10 per cent to 30 per cent), in order to increase the size and strength of the coke. This practice also results, of course, in an increase of the coke yield and decrease in the by-product yields.

Most by-product oven operators in selecting low-volatile coals prefer coals having a volatile-matter content about 16 to 18 per cent (dry-coal basis), although a considerable quantity of coal that does not come within this range is used. True low-volatile coals are not charged in an unmixed condition into by-product coke ovens, because of their expanding properties when coked.

Medium-volatile Coking Coal—There appear to be no well defined, accepted limits for medium volatile coking coals, and usage of this term is known to vary. The writer's personal perference is to include in this class coals ranging from about 22 to 28 per cent volatile matter, dry basis. Such coals have certain coking characteristics which differentiate them from coals having distinctly higher or lower volatile-matter content. The medium-volatile coals, when coked without admixture, nearly always produce a large, handsome, blocky coke that is difficult to surpass in general physical characteristics.

Experience has shown that many of the coals in this class, particularly those having less than 24 to 25 per cent volatile matter, are "neutral" i. e. practically non-shrinking, or even slightly expanding under many operating conditions, in which cases the coke would be difficult or impossible to push from the coke oven. If coking such coal in an unmixed condition in a by-product oven is desired, very careful and thorough tests are required to determine the conditions under which it may be satisfactorily used, and both the quality of the coal and plant operating conditions must be carefully watched to prevent possible trouble. Fig. 9 shows a wharf-full of coke made from 21.1 per cent volatile-matter coal from Washington which was easily pushed from a 14-in. oven on 11 hr. 47 min. net coking time. Other coals of similar volatile-matter content have been successfully coked in the same type of oven.

High-volatile Coking Coal—Enormous quantities of coal ranging from 28 to 35 per cent volatile matter,

(Continued on page 366)

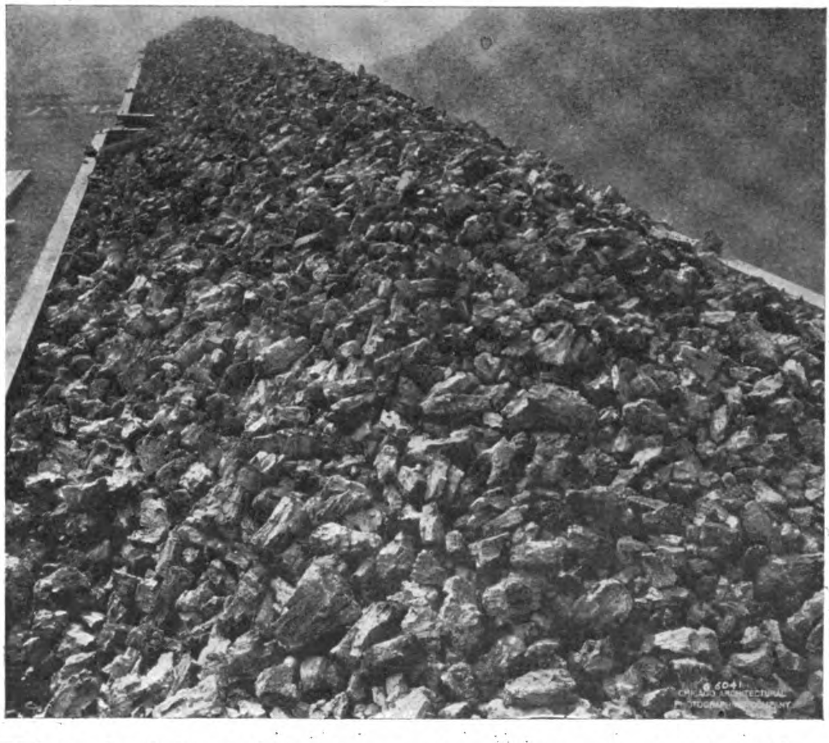

FIG. 10—Loaded cars of blast-furnace coke made from 34 per cent volatile-matter Pittsburgh Seam coal, Fayette County, Pa. Coked in 14-in. Becker type ovens; coking time, 11 hr. 40 min.

General Principals of the Beneficiation of Iron Ores[*]

By T. T. READ[†]

PART III—(Continued)

IN the manufacture of steel it is necessary to employ about 13 pounds of manganese per ton of steel made. Manganese is a not uncommon constituent of iron ore, and if the mangenese in the ore were available for this purpose, it would be quite a simple matter. However, that is unfortunately not the case, and the manganese must be added to the steel as a part of the re-carburizing process. For this purpose ferro-manganese, which contains about 80 per cent manganese, is used. The manganese deoxidizes the steel, and as it contains 5 to 7 per cent carbon it also re-carburizes the steel. Spiegeleisen, which contains 10 to 35 per cent Mn (usually 20 per cent) may also be used in cases where the larger quantity required will not introduce too much carbon into the steel, nor chill it too much, but the larger quantity introduces impurities that are undesirable. By melting spiegeleisen in a cupola and adding it in the molten form the chilling effect can be avoided, but it somewhat complicates the operation. The effect in either case is to refine and "settle" the steel, which then contains FeO from the oxidizing operation that has just been finished, the FeO reacts with the Mn, with the production of MnO. Other substances will even more effectively remove the oxygen, but manganese seems to have the power to free the steel of sonims, which is equally important. The use of manganese alloys in open-hearth practice has been well covered by C. M. Weld and others.

Iron Ores and Manganese Ores—The use of ores high in manganese for the production of ferro-manganese does not concern us here; the use of middle-grade ores for the production of spiegeleisen requires some discussion because between iron ore containing only small amounts of manganese, and manganese ore containing only a small amount of iron, there is every possible gradation, and the point at which an ore ceases to be an iron ore and becomes a manganese ore is not clearly fixed. The simplest definition is one of use; if the ore is used to produce manganese alloys it is a manganese ore, but if it is used like an iron ore it is an iron ore, notwithstanding its manganese content. By this definition ores that on smelting in the blast furnace yield a pig iron containing less than 18 per cent manganese are iron ores, and the problems arising from the presence of manganese in such ores will be discussed below.

Advantages or Disadvantages of Manganese in Iron Ores—The presence of manganese in iron ores may be either objectionable or advantageous. The objections are that manganese is undesirable in pig iron used for certain purposes, and that much of the manganese is lost in the blast furnace, going into the slag. The advantages are that manganese-bearing ores are extremely useful in decreasing the sulphur content of steel, and the manganese present in pig iron decreases the amount of manganese alloy which must be added in steel-making. The distinctions between ordinary steel to which a small amount of manganese is added to deoxidize it and improve its quality, and manganese steel, which contains 12 to 14 per cent manganese, must be kept in mind, because in the latter case twenty times as much manganese per ton of steel (on the average) is involved. Manganese in pig iron is generally believed to retard the transition of austenite into ferrite and cementite; in other words, it has the opposite tendency to silicon, for it tends to keep the carbon in the combined form and make the pig iron more white. In cementite the manganese is isomorphous with Fe, so the formula for it may be written (Fe, Mn)$_3$C. The crystals of manganiferous cementite are usually larger than those of ordinary cementite, they are also harder. For these reasons the makers of malleable iron object to manganese higher than 0.6 per cent, because the product will be hard and difficult to machine, and this is important because the competition in making such objects as pipe fittings, for example, is so strong that an increase in the cost of machining them may be enough to wipe out all the manufacturer's profit. Moldenke sets the limit for manganese in malleable iron at 0. 8 per cent. On the other hand, manganese up to 0.05 per cent is desired because it decreases checking and protects the silicon and iron from oxidizing in the processes of manufacturing; it ought to equal three times the sulphur present to insure that all the sulphur will be in the form of manganese sulphide. As a result, iron ore for making malleable pig is generally specified not to contain over 0.25 per cent Mn. About 3 per cent of the pig iron made in the United States is malleable, so about 3 per cent of the ore must meet that specification.

Manganese in Pig Iron—In ordinary pig iron, manganese is no objection, except in Bessemer pig, where it ought not to exceed 9.5 per cent, but here we encounter the difficulty of the somewhat erratic behavior of manganese in the blast furnace. Manganese quite readily unites with silica to form manganese silicate. An investigation of spiegel furnace practice, given in Bulletin 173, already cited, reveals that the manganese in the slag ranged between 7 and 8 per cent. With moderate amounts of manganese in the blast-furnace charge it would undoubtedly be possible to so operate the furnace as to cause all the manganese to go into the slag. Ordinary pig iron ranges between 0.25 and 1 per cent manganese, but 2 per cent is not uncommon. The average manganese content of Lake Superior iron ores is between 0.6 and 0.8 per cent, which would correspond to about 1.4 per cent Mn in the pig iron if the manganese were all saved, which is not the case. Probably most ordinary pig iron is between 0.5 and 1 per cent manganese, and a considerable part of the manganese charged into the blast furnace is lost in the slag.

What happens to the manganese in the pig iron depends on what process is used for converting it into steel. In the acid-Bessemer process the manganese

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[*] Published with approval of the Director, U. S. Bureau of Mines.

[†] Formerly Safety Service Director, U. S. Bureau of Mines, and Superintendent of North-Central Experiment Station, Minneapolis, Minn.; now Assistant Secretary, American Institute of Mining and Metallurgical Engineers.

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and silicon are the first elements to burn off. In America the Bessemer operator prefers his pig not to carry over 0.5 per cent Mn because more than that makes a liquid slag which causes a good deal of slopping from the converter during the blow and causes dirty ingots from the slag carried over the steel. With the thin slag it is also more difficult to re-carburize the metal. In Sweden, 2 per cent Mn was formerly used in Bessemer practice; the Swedish metal was low in silicon, the principal source of heat in the first stages of the blow. Briefly, we may say that all the manganese of ore used for Bessemer steel is lost in the smelting and steel-making operation; the amount present in the average in American ores is rather more than is desirable for the best operation of the process.

Manganese in the Open Hearth—In the acid open-hearth process practically the same condition obtains, and the manganese in the bath is reduced to only a trace by the time the charge is melted. The contribution of heat by the burning of the manganese is not needed in the gas-heated open-hearth, the manganese yields a base which not only requires SiO_2 to flux it, but increases the amount of slag made, and the lost manganese decreases the yield of steel from the pig iron charged.

In the basic open-hearth, on the other hand, we are counting on the basic slag to eliminate phosphorus, and some of the sulphur and the manganese is useful in providing a base, for basic open-hearth slag contains 10 to 25 per cent FeO. The objections made above, therefore, disappear, and remembering that half of the pig iron made is basic grade, the way is then cleared for the use of any desired amount of manganese in ore. The objection still remains as to the loss of manganese in the blast furnace, but with care this is probably not over a third and the manganese which goes to the steel furnace is advantageous. Insofar as it is not eliminated in the steel-making process, initial manganese produces good effects for which manganese alloys are added, and reduces the amount of such alloys. It is quite possible to operate the basic open-hearth so that instead of the manganese being eliminated from the bath it will not fall below 0.25 to 0.3 per cent, which not only obviates adding that much but also has a very beneficial effect on sulphur elimination.

Another use for manganiferous iron ores is for the ore addition during the steel-making operation. The manganese reduced from the ore enters the bath and produces the good effects mentioned above. Here, however, another consideration enters, and equally applies to the use of high-manganese ores in the blast furnace for acid pig—namely, the phosphorus content of high-manganese iron ore. It is obviously undesirable to add phosphorus in an operation designed to remove it. The principal place in the United States where manganiferous ores are produced is the Cuyuna range, Minnesota. E. Newton* has published an analysis of the so-called high-phosphorus ore from the Cuyuna which shows 0.17 per cent P and 13.5 per cent Mn, which ought not to offer any particular difficulty in the basic open hearth as an ore addition.

Conclusions as to Manganese in Iron Ores—The general conclusion as regards manganese in iron ore is that in any amount that will yield over 18 per cent Mn in the resultant pig iron it is to be considered a manganese ore. In lesser amounts it is extremely useful, both for the production of a 1 to 2 per cent Mn pig iron for the basic open-hearth furnace, and also to add to the bath in the steel-making process because of its helpful effect in aiding in the elimination of sulphur. On blast furnaces making malleable pig the manganese must be kept down, so that the iron will not contain in excess of 0.5 per cent Mn, because of its hardening effect, and for general purposes not over 1 per cent Mn is desired. Vermilion Range ores from the Lake Superior district average 0.1 per cent Mn. Shipments from the Cuyuna district range from 2 to 4 per cent (excluding 1918 when high-grade Mn ore was being produced) and the average for the whole of Lake Superior has not varied much from 0.7 per cent Mn since 1909 (except in 1918, when it was 0.85 per cent Mn). Assuming that there is a 40 per cent loss of manganese in the blast furnace, Lake Superior ores would average a little less than 1 per cent Mn in the resultant pig iron. Allowing for malleable and Bessemer pig, the present ore supply allows for making about a 1.5 per cent Mn basic pig and for adding some manganese-bearing ore in the steel-making process. The known reserves of manganese-bearing iron ore carrying over 2 per cent manganese are certainly much smaller than was at one time supposed, and if the use of manganese as a desulphurizer continues to grow the future demand will at no distant date have to be met by imported manganese ore. As the imported ore carries 48 per cent Mn or better the tonnage involved will, of course, be very much less.

Conclusions as to Manganese in Ores—In short, manganese is not objectionable in a normal percentage in iron ore, unless the ore is of Bessemer grade, or could be used for malleable iron. In non-Bessemer ore the only objection to it is that when it is present the iron is usually correspondingly lowered, and as the smelting plants do not pay for the manganese in iron ore, it is, as far as the producer is concerned, simply a diluent of his ore. The practice of using manganiferous ore in the basic steel-making operation has grown to such an extent, that a premium for its manganese content is now being paid for such ores.

Titanium in Iron Ores.

The discussion of the effect of the presence of titanium in iron ore is one to be approached only with hesitation, for, in the opinion of the writer, it is a matter of no great importance but one on which wide differences of opinion exist.

Some years ago J. T. Singewald, Jr., now of Johns Hopkins University, but then with the U. S. Bureau of Mines, was assigned the task of ascertaining just what the possibilities of the larger deposits of titaniferous iron ore in the United States might be. The results of Mr. Singewald's studies were published in 1913 as Bulletin 64 of the Bureau of Mines and the following quotation is from page 38 of that publication:

> The field investigation of the titaniferous iron ores has given the author the impression that the possibilities of these ores with reference to the iron-ore resources of the country have been grossly exaggerated in many quarters. In the detailed description of the more important deposits of these ores that follows, their commercial aspect is discussed so far as available data make this possible, and the statements made here are in the nature of conclusions based on those discussions.
>
> Least promising are the possibilities of the ores in the ferro-magnesian rich rocks. As a general rule, the deposits are of small and irregular extent, and the ores fine grained and lean. Leaving out of consideration for the moment their titanium content, they are ores that would require magnetic concentration before they could be used in the blast furnace.

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*Manganiferous iron ores of the Cuyuna district, Minnesota. Bulletin 5, Minnesota School of Mines Experiment Station, 1918, 126 pp.

> Further, most of the deposits are inaccessible to adequate transportation facilities. Their situation both topographically and with regard to the industrial development of the country at large is such that there are no prospects of transportation facilities being provided for a long time to come. Hence, to put these deposits on a producing basis, heavy initial expense would have to be incurred for erecting magnetic concentrators and providing adequate transportation facilities. The small extent of most of the deposits and their irregular distribution make those costs prohibitive. Then, their titaniferous character must be taken into consideration. The relations of ilmenite and magnetite in the ores are such that the least favorable results would be obtained in the elimination of titanium by magnetic concentration. In fact, the titanium would be increased together with the iron; so that the higher the iron content of the concentrates, the higher would be their titanium content.

On page 141 Singewald says:

> As regards chemical composition, except for their titanium content, the ores are very desirable. The coarser-grained ores are usually high grade in their natural condition, whereas a magnetic seperation of the leaner ores yields a high-grade concentrate, with the deleterious constituents at a minimum.
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> As the iron industry at present demands large deposits of definite extent, the outlook for most of the deposits of titaniferous iron ore in the United States is not promising. As a rule the deposits are relatively small and of irregular extent and distribution. Further, they are lean to medium grade, and inaccessibly situated as regards transportation facilities. In other words, to put the deposits on a production basis would require a heavy initial outlay of capital, which the size and irregularity of occurrence does not warrant. There are, however, the two large, high-grade deposits of Sanford Hill, N. Y., and Iron Mountain, Wyoming, which are so readily workable that, despite their titaniferous character, their utilization within a few years seems certain.

The following quotation is from the preface to Bulletin 64:

> It is to be regretted that the results of Mr. Singewald's careful study of the ores are chiefly negative. Some deposits of titaniferous iron ore are clearly not as extensive nor as high in iron ore as they were reported to be. Moreover, examination of many samples by metallographic methods has demonstrated that although a large part of the titanium in these ores is in the form of ilmenite, much of this ilmenite is far more intimately associated with the magnetite than has generally been supposed. Part of the magnetite and ilmenite occurs in such large and distinct aggregates that their separation by a magnetic concentration after fine crushing is practicable, but in by far the larger number of samples examined and in practically all the ore bodies that are known to be large enough and rich enough in iron to be of much importance, most of the ilmenite occurs as such fine intergrowths in the mass of the magnetite that a complete separation of the two minerals by any process based on difference of physical properties still seems impractical. Crushing even to 200 mesh would not insure a clean separation of the two minerals. Consequently the problem of utilizing titaniferous magnetites involves the application of chemical rather than physical methods. In short, the problem is not one of eliminating the titanium by milling but of reducing the ores directly by some melting process.
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> Iron ores containing over 1 per cent of titanium are troublesome to smelt in the blast furnace. Though Rossi and other investigators have demonstrated the possibility of eliminating titanium through the formation of relatively fluid slags consisting of complex titano-silicates, there seems to be no inclination on the part of the iron-masters to adopt furnace practice to these conditions. However, as Mr. Singewald points out, it is practicable to use in blast-furnace mixtures small proportions of the concentrates from a magnetic separation of the titaniferous ores with little change in present methods and without danger of choking a furnace. The use of electricity in smelting offers other possibilities. The reduction of titaniferous ores in electrically heated furnaces and the production of iron-titanium alloys by a direct process are problems of such importance that the Bureau of Mines, in connection with its investigations of the treatment of ores and of more efficient methods of smelting, is undertaking experiments with these ores. The results of these experiments will be published in future reports of the Bureau.

It appears from the above that the economic importance of titanium-bearing ores is nothing like as great as has been supposed. The next point is whether there is any real problem involved in smelting such ores in the blast furnace. The discussion that has appeared on this topic has been admirably summarized by R. S. Robertson and does not need to be repeated here. J. E. Johnson says:

> There is much reason to believe that the former verdict against (titanium) was on insufficient ground. * * * There seems to be no longer any reasonable doubt that it is quite possible to operate furnaces successfully on ores containing amounts of titanium which at one time were firmly believed to be prohibitive.

The effect of titanium on iron and steel is discussed by Stoughton. As the effects of titanium in iron and steel can be secured by adding ferro-titanium made in the electric furnace from titanium ores, it is not essential that titanium-bearing iron ores should be smelted in the blast furnace unless it can be done in competition with the smelting of ordinary ores.

The smelting of titanium-bearing ores in the electric furnace for the production of titanium alloys is outside the scope of our present inquiry and the smelting of titanium-bearing ores in the electric furnace for the production of pig iron involves the many problems which beset the smelting of iron ores in electric furnaces. Briefly, it may be said that it has not yet been found possible to make pig iron in the electric furnace at a cost that will enable it to compete with ordinary pig iron, except in a few special cases where the transportation charges on such pig iron are so high as to create the wide margin of excess cost demanded by the electric furnace. Unfortunately, where such transportation costs exist, pig-iron markets are usually small and scattered, so that the production of pig iron in the blast furnace is not likely to attain any extensive development unless the cost of operation can be brought to more nearly compare with the cost of pig-iron production in the blast furnace.

Miscellaneous Elements.

A complete and sufficiently careful analysis of almost any iron ore would show a long list of elements that are present in perceptible amounts. But there are only a few, in addition to those already discussed, that are of sufficient importance to warrant mention here.

If we consider the fact that manganese and titanium, which are so closely associated with iron in the periodic table of elements as shown in Brauner's modification of Mendeleff's original table, are also so commonly found in association with iron ores it might be considered remarkable that the other intervening members of the series do not commonly occur in larger amounts. The series is as follows: Ti, 48.1; V, 51.2; Cr, 52.1; Mn, 55; Fe, 55.9; Ni, 58.7; Co, 59.0; Cu, 63.6. Those not already covered are discussed below.

Nickel—In the above list nickel is closer to iron than manganese is, and yet nickel relatively seldom occurs in iron ore in such large amounts as manganese. Excepting the brown ores of Cuba, Greece and the Celebes (which are considered to have resulted from the alteration of serpentine or some similar rock mass), and some igneous types of iron ore usually of crystalline magnetite or hematite, it is unusual for nickel to occur in iron ore in amounts large enough to call for any comment. Even in these deposits the nickel seldom exceeds 0.6 per cent. On the face of it, it would seem that nickel would be a welcome constituent of iron ore, as it is so useful an addition to steel, making it strong and hard without increasing its brittleness as much as carbon does. Such an assumption is erroneous, for the successful use of an addition agent requires its careful control, and the control of carbon involves taking it all out of the steel and then adding the desired amount. In a blast furnace and steel plant in which nickel-bearing iron ore is used, the nickel-bearing material gets disseminated through the plant, to the great embarrassment of operations in which it is desired to make metal free from nickel. Such ores, instead of being welcomed by the blast-furnace operator are looked upon with aversion, unless the plant is so situated as respect to ores and markets that it can concentrate on the manufacture of nickel steel. From the operator's standpoint it is therefore a matter of satisfaction that nickel does not more commonly appear in any notable amounts as a constituent of iron ores.

Chromium—The foregoing remarks on the subject of nickel may be equally applied to chromium, except that the ores which contain nickel usually contain two to four times as much chromium. This being the case it is fortunate that some of the chromium in a blast-furnace charge passes into the slag, which is not the case with nickel. As the ratio of chromium to iron in these ores is sometimes as high as 1 to 20, and pig iron containing chromium in the ratio of 1 to 100 iron is hard, and double that ratio makes it unfit for foundry purposes, this fact is not of much assistance. However, it is not difficult to eliminate chromium from pig iron in the Bessemer converter, and most of the chromium in the brown ore from Cuba has been eliminated in this way.

Cobalt—The relative scarceness of cobalt as compared with nickel is perhaps sufficient explanation why it does not occur in iron ores in amounts which call for any comment here.

Copper—This occasional constituent of iron ores has already been referred to in the section on sulphur, where it is pointed out that copper, as a constituent of pyrite cinder, is usually removed by leaching and recovered; and if copper occurred in considerable amounts in iron ore it could be handled in this way. Some ores of the eastern United States as well as the brown ores of Cuba, referred to above, contain some copper and yield a metal containing from 0.1 up to 1 per cent of copper.

There is an abundant literature on the subject of the effect of copper in steel, some of it very controversial in character, and it will be sufficient here to note that copper in iron ore, when it occurs in sufficient amount, can be removed by leaching, and when present in smaller amounts can, through using copper-free ores on the blast furnace burden, be kept within desired limits in the resulting pig iron.

Vanadium—This metal is so uncommon as a constituent of the earth's crust that an ore that contained even a few per cent of it would be considered a vanadium ore and treated to recover that metal. It, therefore, does not need further consideration here than to note that its behavior in the blast-furnace charge is much like that of titanium.

Zinc—Some of the smaller ore deposits of the eastern United States contain zinc. As zinc vaporizes at 920 deg. C., the metal rises with the gases and as soon as it reaches a point at which the temperature and the CO_2 concentration permits, it reacts with CO_2 to form ZnO, which may form a "zinc-ring" in the walls of the furnace just below the stock line. The ZnO which condenses in the charge is carried by it back to the zone of reduction and repeats its cycle. Aside from the annoyance to operations resulting from the scaffolding effect on the walls, and the difficulty of removal, the presence of zinc in some iron ores does not call for further comment.

Other Elements—Chlorine, arsenic, antimony, etc., which may occur in minute amounts in iron ores, offer no difficulty in their treatment because they are all volatilized at temperatures much below those prevailing in the blast furnace. Potassium is an element that would naturally be expected to go into the slag, but which in part goes off with the gases. Much has been written on the possibility of making the iron blast furnace a source of potash, but the matter is not one which comes within the scope of this review although reference may be made to the work of Kinney* of the Bureau of Mines.

Brief Conclusions as to Impurities in Iron Ores—This concludes the list of impurities in iron ore which need to be taken into consideration. The general conclusion is that silica constitutes the principal problem in iron-ore beneficiation. Phosphorus can be taken care of by adapting the metallurgical process to the amount present. Sulphur is a coke problem rather than an ore problem. Lime and magnesia are seldom present in amounts in excess of that required in the blast-furnace mixture. Alumina can usually be removed by simple washing process. Excessive moisture adds to transportation costs and when the saving in freight, etc., exceeds the cost of drying plus the problems introduced by dust losses, etc., beneficiation processes to reduce the moisture content are warranted. Silica, when present in amounts over the quantity necessary for making the required amount of slag, increases the cost of pig iron production, and its removal is warranted when the cost does not exceed the resultant saving in cost of pig-iron production. Some of the processes used for this purpose have been referred to in the foregoing discussion, but their detailed study lies outside a general discussion of the principles of iron-ore beneficiation.

Disintegrating and Agglomerating of Iron Ore.

Movement of Charge and Wind in the Blast Furnace—To obtain good operating conditions in the blast furnace it is necessary, not only to have a proper chemical mixture, but also to have a proper physical mixture as well. The reason for this is, of course, that we have to provide for the blowing of 8,000 tons of air a day up through the descending charge while something like 1,000 tons of ore, 500 tons of coke, and 200 or 300 tons of limestone per day is at the same time descending the shaft. It is a fundamental principle of physics that two bodies cannot occupy the same space at the same time, consequently the only way in which the air can get up through the furnace, while at the same time the ore, coke, and limestone are descending it, is to pass between the particles of these solids. If all the particles of each of these three solids were of exactly the same size, no matter what the size might be, the spaces between them would amount to about 50 per cent of the total volume that they occupy. If, however, we have a mixture of large particles and small particles, the small particles tend to occupy the spaces between the large ones so that the volume of the particles reckoned as a percentage of the space which they occupy tends to become larger and larger until with a theoretically perfect mixture of particles of the proper sizes their volume would be practically 100 per cent of the space they occupy or, in other words, there would be no spaces between them. Much study of the problem of getting a mixture of the proper sizes so as to yield a minimum of interspaces has been done by engineers engaged in the proportioning of mixtures of concrete so as to yield a mixture which has the minimum of spaces between the particles, and accordingly gives a maximum of solidity. In the blast furnace we have the opposite phase of the problem because the blast-furnace mixture ought to be so proportioned as to give the maximum amount of spaces between the particles. The reason for this is that the power required to force the enormous quantity of air through the blast furnace is really very considerable and the blowing equipment is perhaps the most expensive part of the blast-furnace plant. The problem in blowing a blast furnace is to get the requisite number of pounds of oxygen to the coke in order to burn the coke away as rapidly as possible, because the more rapidly the coke burns the more effectively will it yield its heat for the production of the desired reactions within the furnace. There is a somewhat general opinion that certain kinds of coke burn more rapidly than others, but so far as is known at the present time there is no evidence to indicate that the rapidity at which coke burns depends upon anything other than the rate with which it is supplied with oxygen for the burning. The structure of a piece of coke has, of course, a considerable influence over the rate at which it can be supplied with oxygen, just as coke can be more rapidly supplied with oxygen than a lump of anthracite coal can, but the basic problem is the supplying of oxygen to the coke and the less resistance to be overcome in doing this the less expensive will the operation be. From the standpoint of getting the blast through the furnace the larger the proportion of open spaces in the blast furnace charge the smaller will be the cost of blowing.

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*Kinney, S. P., and Guernsey, E. W., Occurrence, distribution, and significance of alkali cyanides in the blast furnace. Tech. Paper 390, Bureau of Mines, 1926, (in press).

Size of Charge Materials and Blast-Furnace Reactions—There is another phase of the matter, however, and that is the effect of the size of the particles upon the speed with which the blast-furnace reactions can take place. In the case of the limestone it is undoubtedly true that after it has descended below the point in the furnace at which there is much free carbon dioxide it is converted into CaO or quicklime, which has only 50 per cent of the volume of the original limestone and also, not being very coherent, is probably quickly ground into powder by the movement of the harder particles of the charge. The coke and ore particles are doubtless also somewhat disintegrated during the descent from the top to the bottom of the furnace. The gradual settling of the charge may be compared to the slow movement of a glacier, and the grinding and crushing of the particles against each other unquestionably tends to disintegrate them. It has been found in mining practice that after ore is milled down through chutes several hundred feet in height it will be found, on emerging at the bottom, to have been thoroughly crushed in the descent, even though originally quite hard and coherent. It is unquestionably true that the same sort of action takes place to a limited degree in the blast furnace, although it is impossible to determine to what extent. On this question I would refer the reader to the paper* by T. L. Joseph, P. H. Royster, and S. P. Kinney read before the Blast Furnace Conference of Engineers' Society of Western Pennsylvania, November 12, 1925.

It is obvious, of course, that the iron ore will also suffer a change in volume during the progress of its descent, because soon after passing into the zone of reduction it is changed from Fe_2O_3 to Fe, which corresponds to a shrinkage of 30 per cent in volume. It is not to be supposed that the actual volume decreases to this extent either in the case of the iron ore or the limestone, and what happens is that in place of solid particles they are converted into more or less porous particles by the elimination of the oxygen and carbon dioxide, respectively.

We see, therefore, that the tendency during the progress of the solid materials down through the furnace is to reduce them in size. In other words, large lumps charged into the furnace will tend to be crushed into smaller lumps in progress through it, so that we have to consider not only the relation between large and small particles in the initial charge but also the probable change in that ratio during the progress of their descent.

Size of Iron Ore and Coke—It seems clearly demonstrated at the present time that within unknown limits the smaller a particle of iron ore the more readily is it reduced in the blast furnace. It is self-evident that the smaller a particle of coke the more easily will it be burned, because the speed of burning the coke depends upon the ratio between the surface and the mass, and the smaller the particle the larger is its surface in proportion to its mass.

From this analysis of the problem it would appear that if we could get particles all of a uniformly small size we should have an ideal charge for the blast furnace. The matter is not quite so simple as this, however, because some other factors must be considered. For example: When the ores of the Mesabi range were first mined in considerable quantity they were violently objected to by blast-furnace operators, who said that the particles were too fine and made operation of the blast furnace difficult. It was said that these fine ores caused explosions in the blast furnace, though this is very doubtful. However, if a blast furnace hangs up through the formation of scaffolds on the side, coupled with arching of the charge, until the charge below has melted away and then the scaffold yields, dropping the burden through considerable distance, the effect produced on the blast furnace is almost exactly the same as if an explosion had taken place within it, so that the question is one of terms rather than of effects. As blast-furnace operators learned through experience how to prevent these effects with Mesabi ores, the effects of them gradually disappeared, and at the present time the curious state of affairs exists that two plants have been built to crush Mesabi ores. This is because in steam-shovel mining large lumps of ore can be loaded by the steam shovels and are extremely difficult to handle when they arrive at the ore docks and furnaces.

Objection to Fine Ore—The objections to fine ore are more than one: In the first place the blowing of 8,000 tons of air a day up through the spaces between the charge inevitably means that these gases are passing through the charge with a high velocity, and any particles of ore that are small enough to be lifted by this velocity will be raised up through the furnace by the up-rushing gases instead of descending down it by its own weight. There are two forces acting on a particle in the blast furnace: The force of gravity, which tends to make it descend in the furnace, and the force of the gas pressure, which tends to make it rise. The relative effect of the gas pressure increases

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*Effect of physical properties of ore and coke on the capacity of the blast furnace. Proceedings Engineers' Society of Western Pennsylvania, vol. 41, 1926.

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enormously with the decrease in size of the particles, with the result that small particles are blown out of the furnace with the gases. Not every particle that might be lifted by the gases is blown out, however, because the large particles shelter the small particles immediately behind them and they are thus able to make their way to the bottom, even in the face of high gas velocity. (This condition may be compared to infantrymen advancing behind the shelter of tanks in the face of machine-gun fire.) Nevertheless, a large proportion of the fine material gets blown out of the furnace. Suitable provision has to be made for catching it, which is difficult to do, and it gives more or less trouble in the gas chambers and makes necessary expensive provision for eliminating it from gas that is to be sent to gas engines. The material which is blown out is sometimes collected and charged back into the furnace again, in spite of the obvious fact if it was blown out the first time it can be blown out a second time. The proper treatment is to subject it to an operation for sintering it, as described in more detail below.

Objections to Coarse Ore—The good effect of the large particles in protecting the small ones in descent through the furnace has been mentioned, but large size in a particle is also disadvantageous. If the lumps of ore are very large the time required to convert them from iron oxide to iron is considerably increased and they may even pass through the zone of reduction with a core that is still unreduced. When they come to the zone of melting, the melting time is also increased and therefore large particles, especially of ore, are objectionable in the blast furnace. The miner, therefore, is called upon to furnish the furnace with material that has no lumps that are too large to be reduced and melted readily and without particles that are so small that when they are put in the blast furnace they will be blown out again. When most iron ore was mined by hand underground the problem of large lumps scarcely existed. The ore had to be shoveled into cars underground, and this automatically insured that the miners would break the ore into lumps that were small enough to be conveniently handled.

At the present time, when a very considerable proportion of the ore is mined by steam shovels and is never touched by hands from the time it is first moved from its bed until it reaches the blast furnace, a quite different conditions of affairs exists. The tendency in open-pit mining has been to use larger and larger shovels and ones with buckets of 8-cubic yard capacity are not uncommon. It is quite possivble with shovels of this size to load into the cars; blocks of ore that are too large to pass through the chutes in the ore docks or to be handled by the equipment used for unloading the boats at lower lake ports. The result of this is that the ore arriving at the blast furnaces contains not a few masses that are just under the size beyond which they cannot be handled in transportation. These masses are much too large for the successful working of the furnace, not only because of the long time required to reduce and melt them, but because they accentuate the problem already mentioned of the smaller particles filling the spaces between the large ones and leaving no openings through which the blast can pass.

Example of Screening and Crushing Lump Ore—The problem of how to deal with these large masses is one that is receiving a good deal of study at the present time and no general solution has as yet been reached. At Hibbing, Minn., the Oliver Iron Mining Company has built a screening and crushing plant to handle part of the ore taken from the Hull-Rust pit. This ore comes from a part of the deposit that has been cemented so that it breaks in fairly large lumps and the method of treatment is as follows.

The ore loaded on cars by the steam shovel is taken to a large grizzley made of railroad rails set at an angle of about 45 degrees. The ore is dumped over this grizzley and all particles smaller than 6 inches in diameter pass through the grizzley into a pocket from which they may be loaded into cars for shipment. The oversize is elevated by a belt conveyor to a jaw crusher, whose product goes to bins for shipment. This process is, of course, practically effective in reducing the large lumps to the size desired, but has the disadvantage that it requires subjecting all the ore loaded into the car by the shovel to a re-handling, which is only necessary in the case of a small part of it. As a result of the operation a central screening and re-crushing plant for the mines of the Virginia district was put into operation in 1924.

It would, of course, be possible to subject these large particles to the same process that is now applied to products too large to be lifted by the shovel. Such blocks are pushed to one side by the shovel and are broken by blasting either by mud-capping or block-holing. This method is not only somewhat expensive, but also if it has to be applied to any considerable number of particles tends to interfere with the operation of the shovel itself.

It is, therefore, seen that the problem of how best to handle the lumps that are too large for economical treatment in the blast furnace is one that is now engaging the attention of the miners and mine operators, but no general or satisfactory solution has yet been reached.

In ores which are subjected to the washing processes described in an earlier section, this problem is automatically taken care of because in most cases facilities are provided for the breaking of lumps that are too large.

Agglomerating Iron Ore Concentrates—In the magnetic concentration of ores the problem of too large lumps does not exist, but because of the crushing that is necessary in order to free the magnetic particles, a new problem is created—namely, the production of a concentrate that is too fine for furnace operation. This is especially true of the magnetic concentration of East Mesabi ores because of the fine grinding that is necessary to free the magnetic particles. The process generally applied in magnetic concentration is the sintering of the ores on grates or sintering machines. The fine concentrate produced by the magnetic concentration operations is mixed with a sufficient amount of fine bituminous coal, coke breeze, anthracite sludge, or other carbonaceous material that may be locally available, and sintered on the grates. The lumps of sinter thus produced are in some cases too large and have to be crushed. A certain proportion of the product is also too fine and is often screened out and sent back over the sintering machine if the proportion of such fine material is larger than the furnaces desire.

The use of kilns to sinter pyrite cinder has already been described in the section on "Sulphur in Iron Ore," while the use of kilns to sinter the soft wet ores of Cuba has been described in the section on "Water in Ore." Generally speaking, however, the temperatures used in drying wet ores are not high enough to cause any sintering effect, and the expense of sintering ore by heat is sufficiently large so that it is not to be considered a general solution of the problem.

Conclusion as to Size of Ore in the Blast Furnace—Generally speaking, it would appear, therefore, that the best solution of the problem of how to maintain a proper physical structure inside the blast furnace is to avoid feeding the furnace a mixture of large and small particles so proportioned that the small particles fill the spaces between the large ones to an undesirable degree. Assuming that undesirably large lumps are crushed before they arrive at the blast furnace this could be brought about by screening the ore and the treating of the different sizes in different furnaces. In a plant where more than one blast furnace is operating there is no obvious reason why one stack should not be operated on coarse ore and one on fine, although this would probably involve some difficulty in controlling the chemical constitution of the mixture, because the two products would undoubtedly have a somewhat different composition. This point, to some extent, was discussed at the Blast Furnace Conference of the Engineers' Society of Western Pennsylvania at Pittsburgh, on Nevember 12, 1925, and published in its Proceedings for January, 1926.

Oil-Electric Locomotives to Enter Industrial Field

WITHIN the next month or six weeks the oil-electric locomotive, which has been attracting so much attention lately in the railroad field, will make its initial appearance in mining and lumbering operations.

A locomotive of the 60-ton type, capable of developing 300 hp., and similar in design to oil-electrics that are now in operation at six important railroad terminals in the east and middle west, is being built by the Ingersoll-Rand, American Locomotive and General Electric companies, originators of this type of motive power for the rails, for the use of the Utah Copper Company at its mines at Bingham, Utah. A locomotive of the 100-ton type, 600-hp. capacity, will be delivered at about the same time to the Red River Lumber Company for use in lumbering operations at Westwood, Cal.

Installation in service of these two oil-electric locomotives will mark the first use of this form of motive power at any point west of the Mississippi river, and its first use in mining and lumbering anywhere in the world.

Up to the present time interest in oil-electric motive power has been confined largely to its adaptability to the requirements of the railroads, and there has been but little discussion of its possibilities for other branches of industry.

The manner, however, in which the oil-electric locomotive was inducted into railroad service lends itself readily to a consideration of its possibilities for general industrial use. The tasks of locomotives in railroad yards are closely similar to the work they are called upon to perform in mining and lumbering work, and in steel and manufacturing plants.

Designed for Special Purpose.

The oil-electric locomotive was designed originally to aid in solving a very specific problem—the pressing need of the railroads to curtail the constantly increasing burden of operating costs. This condition was further complicated by a growing public demand for cleaner and more healthful transportation conditions, especially in the larger cities where the smoke and noise of congested railroad terminals had become serious municipal problems. The result was that all the early tests and demonstrations of oil-electric operation have been in railroad service, particularly in switching work at points where the smoke problem was an acute issue.

Excellent Results Possible.

That excellent results are possible of attainment by the oil-electric locomotive in mining and lumbering operations seems assured by tests of similar locomotives in use on the railroads. The 60-ton locomoive, in type similar to the one now being built for the Utah Copper Company, now in use on the Central Railroad of New Jersey in 2,331 hours of locomotive service, extending over a period of six months from October 22, 1925, to the end of April of this year, was operated at a fuel cost of 19.8 cents per locomotive hour. This compares with a fuel cost of $1.14 per locomotive hour for an equivalent steam locomotive engaged in the same kind of work under conditions almost identical at the same terminal.

The work at which this locomotive was engaged was shifting freight and hauling cars on and off floats at the Bronx Terminal of the Jersey Central in New York City. This work is much like what a locomotive is called upon to perform in mining and lumbering operations, where ability to start quickly, to accelerate rapidly, and to move forward or backward with equal facility is of much importance.

Greater Availability.

Tests running over a period of months have shown that the oil-electric locomotive is capable of doing approximately as much work as two equivalent steam engines. This is in part because of its greater availability for service, which is about 80 per cent, or double that of the steam engine, and because no time is wasted in getting up steam in order to start working.

Economy is an essential feature of the oil-electric, aside from its ease of operation and the fact that it is smokeless, noiseless, without ashes and without sparks. The latter factor is of importance in lumbering operations, where care must be taken to guard against incipient fires.

The oil-electric locomotive, in brief, consists of an internal combustion engine, using low grade fuel oil, which drives an electric generator, which in turn transmits power to motors geared to the axles of the driving wheels. Being a self-contained power unit, it can be placed in operation immediately in any kind of service without capital investment other than its own initial cost.

Cost of Maintenance.

It can be operated, it is claimed, at a fuel cost of from one-third to one-sixth that of the equivalent steam engine. It makes possible elimination of coaling plants, ash pits, turn tables, and expensive round house and hostling service. Very little water is required for its operation, thus eliminating costly water equipment and troubles due to bad water conditions. The cost of maintenance of the oil-electric, it is estimated, is but half that of the steam locomotive. Because of its smaller mechanical parts, heavier shop machinery is not required.

The oil-electric is so easy to operate that any steam or electrical engineer can learn to manipulate it in a few hours; and it may be substituted for any other form of motive power without any disturbance of personnel or mechanical equipment of any kind. Two or more of these locomotives can be articulated and operated from a single control station by a single crew.

Low Fuel Cost.

It was demonstrated early in January that a 60-ton oil-electric locomotive can make a long run at an average fuel cost even lower than an automobile. The locomotive was that now in operation on the Baltimore & Ohio railroad and the run, which was made unattached, was over a circuitous route of 733 miles from Erie, Pa., to New York City. The entire cost for fuel and lubricating oil for the trip was $8.75, or 1.2 cents per mile. To operate a Ford costs on an average of 1.66 cents a mile for gasoline and lubricants. A similar locomotive, delivered early in June to the Reading system, made the run of 613 miles from Schenectady, N. Y., to Atlantic City at a fuel cost of $7.78, or an average of less than 1.3 cents a mile. This locomotive attracted much attention at the annual convention of the American Railway Association.

Efficiency and Power.

Another interesting performance was made by the 100-ton oil-electric locomotive owned by the Long Island railroad. This locomotive, similar in type to the one being built for the Red River Lumber Company, starting from Erie, Pa., and hauling a loaded freight train, made the run of 537 miles to New York City without stopping for fuel or water. The cost of fuel and lubricating oil for the trip was only $26.15, or an average of less than 5 cents a mile. The efficiency of this locomotive was demonstrated at one point during the run when it pushed a stalled freight train of 62 cars over a one per cent grade without uncoupling its own load. A previous test at Erie showed this locomotive with a trailing load of 1,315 tons starting from a standstill on a one per cent grade and acceleratng up the grade to a speed of six miles an hour.

Meets Any Requirement.

The oil-electric locomotive can be adapted to meet any railroad or industrial requirement. While up to now its use has been confined entirely to yard and switching service, it can be geared to the speed of the fastest expresses and contains the possibilities of a trans-continental run without necessity for a single stop for fuel or water. Locomotives of 300 and 600 hp. are now in regular use on American railroads. A 750-hp. unit has been ordered and is now under construction, and designs have been completed for an oil-electric of 1500 hp.

Where Now in Use.

Oil-electric locomotives are now in service on the Central Railroad of New Jersey, the Baltimore & Ohio, the Lehigh Valley, the Long Island and the Erie railroads, all in the New York territory, and on the Chicago & Northwestern Railway in Chicago. The most recent installation was on the Reading system in Philadelphia. In addition to these roads oil-electrics have been ordered by the New York Central, the Delaware, Lackawanna & Western, and the Chicago & Great Northern. The latter engine is destined for use at St. Paul, Minn.

Protective Coatings for Metals

(Continued from page 343)

sheets and galvanized sheets containing various weights of zinc coatings; the sheets being exposed to very severe service conditions in three different cities.

It has been found that the finer grained the rust is the slower will be the rate of corrosion, such fine grained rust having the property of permitting the sheet to dry more quickly than sheets containing spongy and coarse grained rust.

A vitreous enameled sheet to which the coating has been fused at approximately 1500 deg. F. has the very desirable property of quickly shedding water when used for roofing purposes. It has been found that the vitreous enamel affects the surface tension of the water so that it forms in globules and rolls off the sheets instead of spreading over them in the form of a film which occurs on other roofing products. Corrosion is essentially the result of the action of oxygen and water and it is obvious that if the sheets dry more quickly and if the water does not adhere to them the rate of corrosion will be decreased.

It has been found that an enameled sheet when dipped into water and allowed to dry, will retain only one-third as much water as a weathered galvanized sheet or uncoated sheet.

It is a recognized fact that under severe service conditions, dependance must be placed upon the coating if rust resistance is desired. It, therefore, becomes unnecessary to use heavy gauge material when using vitreous enameled sheets.

The vitreous enameled coating has a very low specific gravity, and is from two to three times as thick as the average galvanized coating on sheets.

Vitreous enameled sheets should give very satisfactory service under conditions surrounding chemical plants, blast furnaces, foundries, and under alkaline conditions such as may prevail where alkalies are produced or used.

Carnegie Issues Books

Carnegie Steel Company, Pittsburgh, has just issued the first edition of a 196-page book, "Structural Steel Shapes." This book contains information and tables for engineers and designers and other data pertaining to structural steel manufactured by the company. The Carnegie company also has published a booklet giving information on light-weight wrought steel wheels for freight car service.

World's Largest Blooming Mill Completed

THE 54-in. two-high reversing blooming mill recently completed at the Youngstown plant of the United Engineering & Foundry Company for the Homestead Works of the Carnegie Steel Company, in addition to being the largest blooming mill in the world, is of special interest in several ways. The entire mill is of massive construction throughout and with the exception of a few minor parts the castings are all made of steel. Incorporated in the design are the latest improvements in blooming mill practice, including several exclusive features. Due to the large dimensions necessary for the mill, it was practically impossible to obtain sufficient spread of bed plates or a suitable arrangement of feed rollers in a one-piece housing, because a one-piece housing having these parts properly proportioned was entirely beyond either casting or shipping limits. Therefore, a built-up housing assembly made up of four post sections and a top and a bottom separator was designed similar to the housing arrangement built for the 206-in. four-high plate mill at the Lukens Steel Company, Coatesville, Pa. These plate mill housings have been in operation for about nine years and have been entirely satisfactory. The finished weight of the housing assembly is about 800,000 lbs.

The top separator which carries the two screw boxes also forms the top center blocks for the four housing legs. The bottom separator and center blocks are also cast integral. The top of this casting is a slide for the roll changing rig. The housing legs are clamped to the center blocks by steam shrunk bolts at the top and by heavy shrink links at the bottom. Flange bolts are also used to assist in securing the legs to the center blocks, but the main reliance is placed upon the shrink links and bolts. The rolling pressure is transmitted from the center blocks to the legs by an interlocking tongue and groove construction with tapered cross keys to prevent lost motion. The bearing areas of the tongues is large enough to reduce all stresses below the possibility of any deformation due to rolling pressure.

This construction, it is claimed, has the following advantages over solid housings:

1—Ample spread of bed plates was obtained without encountering shipping difficulties.

2—Feed rollers were more suitably accommodated.

3—Casting stresses and defects were less probable than in solid housings.

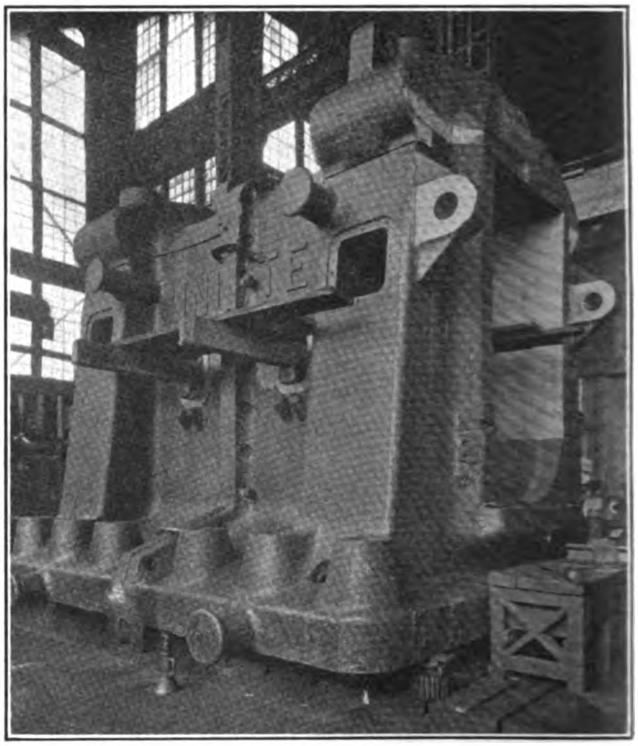
4—The built-up housing is heavier than any housing it was possible to cast in one piece, thus giving an increased "anvil" effect which is valuable.

The shoe plates are of very massive section, machined flat on top. They have a depth of 6 ft. 0 in. Cross ties are provided underneath each end to which the shoes are keyed.

The screwdown is of the spur and bevel gear type driven by two 150-hp. motors connected in series. An interesting and important feature of the screwdown is the method of adjusting rolls. This method consists of dropping one of the bevel gears out of mesh, which can be done by one man in a few minutes from the platform, thereby permitting the lining up to be done with the opposite screw.

Two solid forged steel rollers on each side of the mill act as feed rollers; those nearest the rolls being carried in a bore in the housing. The others carried in bearings on the face of the housing. These rollers are driven by a train of enclosed gears carried in a separate housing on the shoe plates, which, in turn, is driven from the last roller in the mill table.

The rolls are balanced by a hydraulic cylinder in the usual way and the weight of the couplings is balanced by an auxiliary cylinder. To reduce roll changing time to a minimum, the housing fillings were specially designed and a motor-operated roll changing rig provided. With this rig, both top and bottom rolls are moved out of the housings at one time, then moved sideways and a new set of rolls put in place to be moved into the housings. This operation is made possible by providing the top roll carriers with legs which are allowed to rest on the bottom carriers when the keys at the suspension bars are removed and the screws run up carrying the top riders away from the top roll.

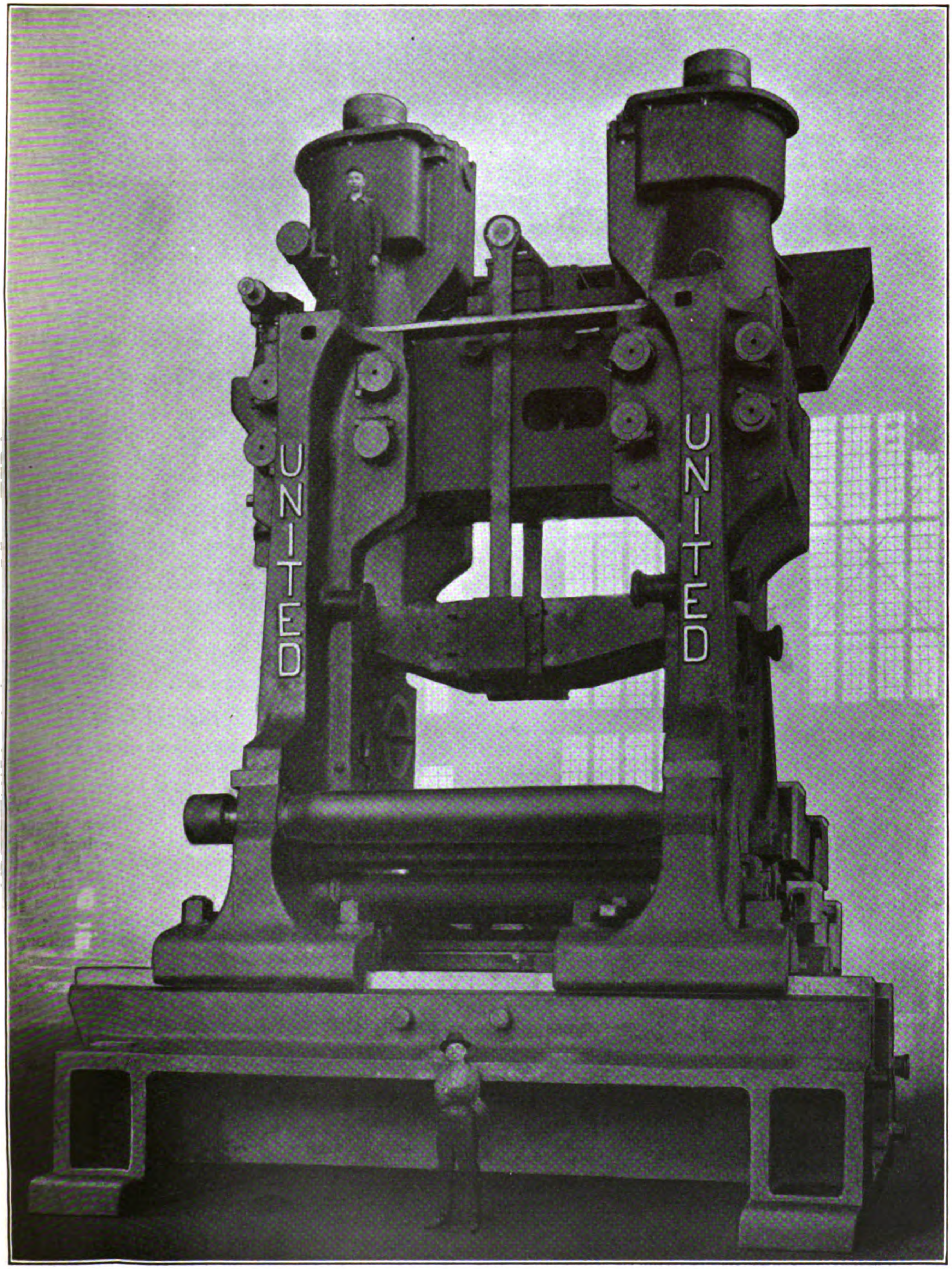


Pinion housing—Finished weight of pinion housing and cap, as shown, 353,000 pounds.

The pinion stand is mounted directly on the foundation and is fully enclosed. The pinions have double helical cut teeth. The spindles are of the improved Geer universal type.

The entry and front and back mill tables have entirely enclosed drives and gearing. Six entry rollers in receiving table and 22 in front and back mill tables (including feed rollers) are solid forged steel, the other rollers are hollow cast steel with forged trunnions. All gears are forged and have cut teeth and are arranged to dip in oil. All drive and side shaft bearings are of the chain oiling type.

The manipulator is entirely motor-operated, and is double, i. e., on both sides of the mill and has tilting fingers on one side guard on both entry and delivery



Fifty-four inch two-high reversing blooming mill built by United Engineering & Foundry Company for the Carnegie Steel Company, Homestead.

tables. It is of the overhead type and has all the operating mechanism on the pinion side of the mill.

Each side guard is operated by two forged steel rams, to which the side guards are attached in such a manner that expansion and contraction cannot cause binding of the rams in their slides. The rams are connected to the drive by links and levers.

PRINCIPAL DATA

Pitch diameter of pinions	54 in.
Face of pinions	72 in.
Lift of top roll	40½ in.
Length of roll body	120 in.
Approximate finished weight of each roll	97,000 lbs.
Diameter housing screws	16 in.
Screwdown motors	(2 each) 150 hp.
Center to center shoe plates	15 ft. 6 in.
Distance across housing feet	19 ft. 0 in.
Height of mill above top of shoe plate	31 ft. 1¾ in.
Total height of mill, including shoe plates and supports	38 ft. 0¾ in.
Size of ingots	30 in x 45 ft.
Weight of ingots	30,000 lbs.
Total finished weight of mill—Roll changing device, pinion stand, spindles and carries and mill tables	3,833,000 lbs.
Total finished weight of manipulator	1,456,000 lbs.

Each set of tilting fingers is operated by forged steel levers and a crank motion, which is equalized to insure horizontal motion of fingers across tables. The only direct connection of the manipulator with the tables is at the slides for the rams, which are well below the top of rollers and are protected from scale.

Two lubricating pumps are provided which are operated by the manipulator mechanism. The pumps automatically lubricate all the slides. Each pump holds one and one-half barrels of oil or grease.

To Study Mining and Metallurgy

Thirteen graduates of colleges and universities have been appointed Research Fellows to conduct an unusually extensive program of studies in mining and metallurgy at the Carnegie Institute of Technology during the coming year, according to an announcement. The work, as in the past, will be carried on by the Department of Mining and Metallurgical Engineering, in co-operation with the Pittsburgh Station of the U. S. Bureau of Mines and under the direction of two advisory boards of engineers and business men representing the mining and metallurgical industries.

The appointees and the institutions from which they were graduated are Clarence L. Corban and G. R. Fitterer, Rose Polytechnic Institute; Briant F. Branting, University of Utah; R. L. Geruso, Rensselaer Polytechnic Institute; Charles H. Gilmour, Syracuse University; E. R. Perry, Hastings College; Miles B. Royer, Pennsylvania State College; E. J. Talbert, University of New Hampshire; N. A. Tolch, University of Illinois; Carl E. Traubert, University of Denver; Stanley P. Watkins, Birmingham Southern College; R. E. Wiley, University of Minnesota; Donald C. Jones, Carnegie Institute of Technology.

Of the 13 investigators, five will study problems in metallurgy and eight have been assigned to carry on research in problems relating to coal mine engineering. The program of metallurgical studies will be supervised officially by an advisory board of Pittsburgh District steel men and engineers. The coal mining investigations will be made under similar conditions with an advisory board of coal operators and mining engineers.

Four of the studies, it is announced, will be financed by the Carnegie Institute of Technology, while the remainder of the work will be underwritten by the industries. Among the contributors are the American Gas Association, which is interested directly in a study of "warning agents for manufactured gas," the National Coal Association, the New York Edison Company, and other industrial enterprises.

Senior investigators to assist the Research Fellows will be furnished by the Bureau of Mines. Problems have been selected and assigned for the year as follows: "Constitution of Low Temperature Tar," by B. F. Branting, Fellow, and R. L. Brown, senior; "Coal Ash Fusibility as Related to Clinkering," by C. L. Corban and E. J. Talbert, Fellows, and P. Nichols and A. Selvig, Seniors; "Formation and Identification of Inclusion in Steel," by G. R. Fitterer, Fellow, and C. H. Herty, Senior; "Solubility of Iron Oxide in Iron and Its Effect on Physical Properties of Pure Iron," by R. L. Geruso, Fellow, and C. H. Herty, Senior; "Flammation of Fine Sizes of Coal Dust," by C. H. Gilmour, Fellow, and C. M. Bouton, Senior; "Electric Power of Storage Batteries vs. Trolley Locomotives," by Donald C. Jones, Fellow, and L. C. Illsley and C. W. Owings, Seniors; "Warning Agents for Manufactured Gas," by E. R. Perry and E. J. Talbert, Fellows, and S. H. Katz, Senior; "Viscosity of Open Hearth Slag," by M. B. Royer, Fellow, and C. H. Herty, Senior; "Mine Timber Treatment," by N. A. Tolch, Fellow, and L. D. Tracy, Senior; "Distribution of Ferrous Oxide between Slag and Metal," by S. P. Watkins, Fellow, and C. H. Herty, Senior; "Case Carburizing of Steel," by R. E. Wiley, Fellow, and C. E. Sims, Senior.

Watt's Workshop Saved

The little, littered workshop in which James Watt, called the "Father of Steam," carried on his experiments which resulted in the steam engine, has been rebuilt in the British Science Museum, where Watt's lathe, forge and simple tools have been placed and where visitors can even see his worn leather apron hanging on a nail, exactly as he left it at his death, in 1819. At the same time the home of the inventor, near Birmingham, was announced for sale, but the garret room in which he did his epoch-making work will be saved, as a shrine for future generations, through its incorporation in the Museum.

If Watt could visit a modern electric generating plant he would hold up his hands in horror, it was remarked recently, to see steam used at a pressure of 350 pounds to the square inch, producing a kilowatt-hour from a pound and a half of coal. When Watt built his steam engine, about a century before the first electric central station was established, he believed that six pounds of steam was the limit for safety. When, in 1797, the first Cornish boiler was built and operated under a 25-pound pressure, Watt denounced its designer, Richard Trevethick, as a "murderer."

Today 350-pound pressure to the square inch is the accepted rating of large utility plants. A few in operation record 700 pounds and more recently an experimental plant designed for the terrific pressure of 3,20 pounds was announced, more than 500 times the limit sett by Watt.

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By VICTOR S. POLANSKY*

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Relates to a high-manganese steel, wherein the product is required to have from 10 to 14 per cent and upward of manganese, with carbon less than 2 to 3 per cent.

Hadfield, Robert A. Improvements in or Relating to Remelting of Manganese Steel Scrap. (British patent, 130,436.)

Relates to remelting of scrap in such manner as to avoid loss of manganese, at the same time producing steel in which iron, carbon and manganese are present in required proportions.

Hadfield, Robert A. Improvements in or Relating to the Manufacture of Manganese Steel. (British patent, 124,817.)

Relates to manufacture of high-manganese steel.

Hadfield, Robert A. Improvements in or Relating to the Manufacture of Manganese Steel. (British patent, 125,157.)

Relates to manganese steel possessing great toughness and resistance to perforation.

Hadfield, Robert A. Improvements in or Relating to the Manufacture of Manganese Steel Sheets and Helmets Made Therefrom. (British patent, 133,131.)

Hadfield, Robert A. Improvements in the Manufacture and Treatment of Self Hardening Steel. British patent, 16,049 of 1884.)

Object is to produce, at a greatly reduced cost, an improved self-hardening, manganese steel, which is naturally hard, either in its cast or forged state.

Hadfield, Robert A. Improvements in the Manufacture of Manganese Steel. (British patent, 25,794 of 1903.)

Object is to produce a high-manganese steel of low carbon content. Instead of ferromanganese, use is made of an electric furnace alloy of 70 to 90 per cent manganese and 2 or 3 per cent carbon.

Hadfield, Robert A. Improvements in the Manufacture of Steel. (British patent, 200 of 1883.)

See also British patent, 8268 of 1884.

Manganese steel, the manganese varying from 7 to 20 per cent.

Hadfield, Robert A. Improvements in the Manufacture of What is Known as Manganese Steel. (British patent, 13,847 of 1893.)

Devoted to the manufacture of manganese steel by which iron is wholly or to a great extent decarbonized and refined, or steel while in course of manufacture is treated with a sufficient proportion of rich ferromanganese.

Hadfield, Robert A. Improvements in the Toughening of Manganese Steel. (British patent, 5604 of 1902.)

See also British patents, 11,833 of 1896 and 4981 of 1903.

Manganese steel is heated gradually, to a temperature of from 750° to 800° C. in order to prevent sudden expansion. The rate of heating depends on the thickness of the steel.

Hadfield, Robert A. Improvements in the Toughening of Manganese Steel. (British patent, 4981 of 1903.)

See also British patents, 11,833 of 1896, and 5604 of 1902.

Hadfield, Robert A. Improvements in the Treatment of Steel with Ferro-Manganese. (British patent, 8268 of 1884.)

See also British patent, 200 of 1883.

Further improvements in treatment of high-manganese steel.

Hadfield, Robert A. Iron Alloys with Special Reference to Manganese Steels. 1893. (In Transactions of the American Institute of Mining Engineers, v. 23, p. 148-196.)

The same. 1893. (In Engineering and Mining Journal, v. 56, p. 106-116.)

The same. 1893. (In Industries and Iron, v. 15, p. 314-315, 358-359, 410-411, 419-420, 452-453, 482-483.)

The same, abstract. 1893. (In Journal of the Iron and Steel Institute, v. 44, p. 513-516.)

Discusses at considerable length the subject of iron alloys, and more particularly describes manganese steel.

Hadfield, Robert A. Iron and Steel Alloys. 1904. (In Iron and Steel Magazine, v. 7, p. 3-21.)

Effect of various elements on iron, including a brief discussion of the properties of manganese steel, p. 6-7.

Hadfield, Robert A. Magnetic Properties of Alloys. 1912. (In Transactions of the Faraday Society, v. 8, p. 94-96.)

Considers the remarkable properties of manganese steels, and states that it is impossible to predict the nature of any particular ferro-alloy unless the whole series of combinations is worked out.

Hadfield, Robert A. Manganese Steel. 1888. (In Journal of the Iron and Steel Institute, v. 33, p. 41-77.)

Discussion, p. 78-82.

The same, condensed. 1888. (In Engineering, v. 46, p. 228-229, 292-294.)

The same, condensed. 1888. (In Iron, v. 32, p. 175-178.)

The same, abstract translation. 1888. (In L'Electricien, v. 12, p. 702-704.)

The same, abstract translation. 1889. (In Oesterreichische Zeitschift für Berg- und Hüttenwesen, v. 37, p. 13-15.)

Confined mainly to the results of author's experiments, but includes some historical data on manganese, ferromanganese and the manufacture of ordinary steel. Contains a brief bibliography.

Hadfield, Robert A. Manganese-Steel; with an Abstract of the Discussion upon the Papers; ed. by James Forrest. 1888. Institution of Civil Engineers.

Contents: Manganese in its application to metallurgy. Some newly-discovered properties of iron and manganese.

The same. 1888. (In Minutes of Proceedings of the Institution of Civil Enginers, v. 93, p. 1-126.)

The same, abstract. 1888. (In American Manufacturer and Iron World, v. 42, no. 14, p. 21.)

The same, abstract. 1888. (In Engineer, v. 65, p. 223.)

The same, abstract. 1888. (In Engineering, v. 45, p. 246-247.)

The same, abstract. 1888. (In Iron Age, v. 41, pt. 1, p. 518-519.)

The same, abstract. 1888. (In Journal of the Society of Chemical Industry, v. 7, p. 211-212.)

The same, abstract. 1888. (In Railroad Gazette, v 20, p. 204.)

The same, abstract. 1888. (In Scientific American Supplement, v. 25, p. 10219-10220.)

The same, abstract translation. 1888. (In Stahl und Eisen, v. 8, p. 300-303.)

The same, abstract translation. 1888. (In Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1888-188 p. 93-94.)

Summarizes work of former investigators and gives results of his own experiments with varying percentages of manganese, discussing the physical properties noticed in the material, and the conclusions to be drawn therefrom.

Hadfield, Robert A. Manufacture of Manganese Steel. (United States patent, 1,310,528.)

Relates to manufacture of steel, comprising iron, manganese, carbon and silicon.

Hadfield, Robert A. Manufacture of Manganese-Steel Rails or Shapes. (United States patent, 791,18

(To be continued.)

Molybdenum as an Alloying Element[*]

Heat Treated Molybdenum Steels Possess High Elastic Limit, Reduction of Area and Impact Value and Great Durability When Subjected to Abrasive Wear

By JOHN D. CUTTER[†]

THE ancient Greek word for lead was molybdos, while substances resembling lead were called molybdaena. In more modern times this latter word was used to designate both the minerals graphite and molybdenite which were thought to be the same because of their close physical similarity. Molydenite or molybdenum sulphide (MoS_2) is the common form in which the metal occurs in nature. It was proved to be distinct from graphite in 1778 by Scheele while Hjelm 12 years later first isolated the element and called it molybdenum. It was classified by Mendeleef in the sixth group of the periodic system.

Until very recently this metal was looked upon as a decidedly rare element and its use on any broad commercial scale was not thought of. In the early part of the 20th century the use of molybdenum was limited to certain chemical reagents. About 1910 the development of the tungsten filament incandescent lamp called attention to the properties of metallic molybdenum wire which was found to be much less brittle, more ductile, and easier to fabricate than the tungsten wire. Though it was not found suitable for the filament itself its use in the brackets on which the filaments are wound played an important part in the commercializing of the tungsten lamp, which, of course, has entirely replaced the old carbon filament lamp.

During the prewar years some considerable work was done by steel investigators with a view to determining the value of molybdenum as an alloying element in steel. The advent of high speed tool steel led to many efforts to employ molybdenum in quantities greater than 1 per cent as a substitute for tungsten. These were never wholly successful and even to date no steel has been successfully marketed containing more than 1 per cent molybdenum. There are drawbacks which accompany the higher contents which will not be discussed here. Suffice it to say that these are not present when fractional percentages are used. Leon Guillet in 1904 and Thomas Swinden in 1911 called attention to the beneficial effects of small additions of molybdenum on the strength and toughness of steel and thus blazed the way for the big events in connection with molybdenum strength steels which occured during the war.

There were several reasons for the revolutionary developments of the war period which started molybdenum on the way to its present prominent place in the alloy steel industry.

The supply of tungsten in the allied countries was seriously threatened. High-speed cutting tools were absolutely essential to the production of munitions. While molybdenum, as stated above, does not make an entirely satisfactory high-speed steel, still it does impart similar cutting qualities, and in view of the shortage of tungsten, offered the best available substitute. Further it became known that the Germans were using molybdenum-bearing steels in certain ordnance and it was a policy of the allies to purchase material for which they may not have had urgent need, simply to keep it out of the hands of the enemy. Accordingly there was a great demand for molybdenum ore, chiefly stimulated by the British Government. This led to the discovery that far from being a rare metal, this element is very widely distributed in the earth's crust. In particular the enormous deposit in Colorado was unearthed which in itself is sufficient to afford quantities far in excess of any demand that can be anticipated.

With this changed picture of the commercial availability of a powerful steel toughener, a systematic research was undertaken by C. H. Wills with the assistance of H. T. Chandler. They investigated thoroughly the advantages of molybdenum in steels where high elastic properties, resistance to wear and fatigue are required. They also covered the same ground with all other available chemical elements and reached the conclusion that molybdenum steels offered the best possibilities for the future. As a result these steels were largely used in this country during the war in the manufacture of aeroplanes, tanks, etc., and since the war have continued to grow in favor, especially in the automotive industry, until today there is scarcely a motor car or truck to be found in which molybdenum steel is not incorporated.

Occurrence and Production.

Molybdenite is a soft, flaky, lustrous mineral which contains 59.95 per cent molybdenum. It is found in many countries, the principal deposits being in Norway, Austria, Canada and the United States. The usual occurrence is in mineralized veins of varying and uncertain width, continuity and richness of ore. At Climax, Colo., however, is the world's largest deposit and chief source of supply. This differs from all other known deposits in that the molybdenite is finely and uniformly distributed throughout a great mass of rock and is practically free from all impurities. In magnitude, methods of extraction, etc., this is comparable to the well-known porphyry copper deposits and alone is sufficient to guarantee indefinitely an unlimited supply of the metal at a cost which permits wide commercial use.

The ore, which contains about 1 per cent molybdenite, is mined, crushed, and concentrated by means of flotation to a product which runs about 85 per cent of the sulphide MoS_2. The balance is siliceous matter persisting from the crushed rock. These concentrates are shipped to the conversion plant and put through a roasting furnace which burns off the sulphur and also oxidizes the molydenum, the product being raw molybdic oxide (MoO_3) which still contains a percentage of silica. This is the base product from which all the finished forms in which molybdenum is used are manufactured.

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[*] From U-Loy News.

[†] Vice President and Metallurgist, The Climax Molybdenum Company.

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Pure molybdenum is a white, soft, ductile metal resembling platinum. It has the following characteristics:

Specific Gravity	9 (about)
Atomic Weight	96
Melting Point	4,500 deg. F. (about)
Specific Heat	0.72
Specific Resistance	5.39
Co-efficient of Expansion	5.1 x 10^{-6}
Tensile Strength	260,000 lbs. per sq. in.
Valence	3, 4, 6

It is made by dissolving the molybdic oxide in ammonia, thus eliminating the siliceous matter and from this solution crystallizing chemically pure ammonium molybdate. This is heated and reduced by hydrogen to pure molybdenum powder which is pressed and solidified by passing a strong electric current through it. The resulting ingot is rolled and drawn into the required sizes of sheet and wire. Its use is practically limited to the brackets in incandescent lamps although in some radio tubes molybdenum plates are used.

The compounds of molybdenum used in commerce outside the steel industry are molybdic oxide (MoO_3) usually called molybdic acid, and sodium molbdate (Na_2MoO_4). They are made by processes of solution and crystallization similar to the above. The former is used in chemical laboratories as a reagent. The latter has a limited use in the manufacture of colors.

Adding Molybdenum to Steel.

The form in which molybdenum is now added to electric and open hearth steel baths in this country is calcium molybdate ($CaMoO_4$). As produced for the steel trade it has a percentage of silica with it, for it is simply the oxide product of the roasting furnace treated with lime to form the calcium salt and still containing the silica component of the molybdenite concentrates. This silica, far from being detrimental, is a distinct advantage as will appear.

When this salt comes in contact with the molten iron of the steel bath, a remarkable reaction takes place based on the fact that iron has a greater affinity for oxygen than molybdenum. The latter is reduced to the metallic state and enters the steel in absolutely pure form, taking nothing with it, as all other components of the addition are strictly slag-forming elements. Not only is the pure element thus available free from all traces of contamination, but the molybdenum is in the nascent or atomic state which greatly enhances its possibilities for effectively combining in the steel. The silica acts as an offset to the lime which is liberated by the reaction and thus furnishes a practically neutral compound which can be used in either acid or basic furnaces with equal effectiveness.

In this respect nature has been extremely kind to molybdenum as it is the only one of the steel tougheners capable of being introduced by the above method which has an even more important advantage than has yet been mentioned.

Calcium molybdate contains no carbon or carbides. The common ferro alloys are smelted in electric furnaces at extremely high temperatures and carbon is used as a reducing agent. This makes it possible that carbides are formed in the ferro alloys themselves which are not broken up at the lower temperature of the steel bath and maybe persist as undesirable segregations in the finished steel.

The process of employing calcium molybdate as the vehicle for introducing molybdenum into steel instead of ferro molybdenum was invented by Alan Kissock and has met with such favor that today there is virtually no ferro molybdenum used in this country.

Effect in Steel.

Molybdenum forms carbides in steel which are extremely strong and hard and exceptionally resistant to wear. It also dissolves in the ferrite, producing remarkable toughness. It has little effect on the ascending or A_c critical point, but produces a marked depression of the descending or A_r point. It is a strong retarder of grain growth and exhibits a powerful tendency to retain carbides in solution on cooling. It apparently has a stabilizing effect on the ability to produce steels uniform as to "normality." Many of the outstanding characteristics of molybdenum steels are the natural sequences of the foregoing.

Characteristics of Molybdenum Steels.

The physical properties of heat-treated molybdenum steels which are most prominently brought out by comparative tests are high elastic limit and especially reduction of area in the tensile test, high impact value, and great durability when subected to abrasive wear. Likewise production tests prove that molybdenum steels "throw the scale," making clean forgings, have wide ranges in heat treatment, affording greater uniformity of product and above all show a degree of machineability which is truly remarkable and is a powerful influence in the rapid growth in the use of these steels.

The four types of molybdenum steel listed in Table I have been adopted as standard steels by the Society of Automotive Engineers.

Selection of Coals for Coke Manufacture

(Continued from page 349)

dry basis, are used in by-product coke ovens. Some of the largest plants coke such coal in an unmixed condition; many others use mixtures in which such coals are the principal components. High-volatile coking coal is produced from many seams and in many States, but the Pittsburgh seam coal from Pennsylvania and West Virginia is probably the most famous, because of the great extent of the seam and the large quantity of coking coal which is produced.

Recent improvements in coke-oven design have greatly increased the coking possibilities of straight high-volatile coals. Fig. 10 shows loaded cars of blast-furnace coke produced from 100 per cent Pittsburgh seam coal with 34 per cent volatile matter.

In the broadest sense, the term high-volatile coking coal includes both gas coals and high-oxygen coking coals.

TABLE I—TYPES OF MOLYBDENUM STEEL.

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range	Nickel Range	Molybdenum Range
4130	.25-.35	.40-.70	.04	.045	.50-.80	....	.15-.25
4140	.35-.45	.40-.70	.04	.045	.80-1.10	....	.15-.25
4150	.45-.55	.40-.70	.04	.045	.80-1.10	....	.15-.25
4615	.10-.20	.30-.50	.04	.045	....	1.25-1.75	.20-.30

Building Project Outlined by Westinghouse

The present building program for the expansion of facilities at various plants and offices of the Westinghouse Electric & Mfg. Company, will involve an expenditure of $5,525,000, according to T. P. Gaylord, acting vice president of the company.

New factory structures or office buildings are now in course of construction at East Pittsburgh, Pa., headquarters of the company and at Mansfield, Ohio, Detroit, St. Louis, East Springfied, Mass., Sharon, Pa., and Derry, Pa.

The cost of the new general office building now nearing completion at the East Pittsburgh works of the Westinghouse Company is $1,500,000. The structure is 11 stories high, with a floor area of 165,000 square feet. This space is designed for the accommodation of 1,800 employes. The building is scheduled for completion late this summer.

Plans for the construction of a $500,000 storehouse for finished products at the Mansfield works of the company have been approved. The building of steel-brick design will be four stories high and will have a floor area of 130,000 square feet. This is the third building to be erected by Westinghouse at Mansfield since the company moved there from Flint, Mich.

The building under construction in Detroit represents an expenditure of $400,000. The building is four stories, of concrete construction with brick exterior. It will have a floor area of 100,000 square feet. It has been designed for use as office, warehouse and service station.

The George Cutter organization of the Westinghouse interests has under construction a $300,000 building in St. Louis, Mo. This structure will be used as a cement pole plant—a new Cutter industry. The building is one story high and will have a floor space of 38,000 square feet.

Plans have been completed for additional buildings at the East Springfield Works that will represent an outlay of approximately $475,000. The principal part of the program calls for a three-story office building. The offices of the new building will provide executive rooms for the engineering, sales, drafting and mechanical departments. The cost of this building will be $275,000.

A four story extension to be built on the main factory will be of heavy mill-type construction. This together with other improvements, will cost in the neighborhood of $200,000.

Plans are being prepared for construction work that will entail a cost of $275,000 at Sharon, Pa. The program includes for a five-story building for light manufacturing purposes. The structure will be mill type of brick-steel construction. A one-story building also will be erected for heat treating and galvanizing work.

A $75,000 office building is now under construction in Derry, Pa. The building will be two stories in height. It will be of steel-brick construction.

A.S.S.T. Announces Tentative Program

The national meetings and papers committee of the American Society for Steel Treating, composed of Earl Smith of Central Steel Company, chairman; H. M. Williams, Delco-Light Company; J. H. Nead, American Rolling Mills and Ray T. Bayless, editor of Transactions of A.S.S.T., secretary, held a meeting in Cleveland recently and adopted the following outline of events for the convention of the A.S.S.T., and the Eighth National Steel and Machine Tool Exposition to be held in Chicago the week of September 20.

The exposition will occupy the entire capacity of Municipal Pier, all of the available exhibit space of which has been reserved. The technical sessions will be held at the Drake Hotel, which is Convention headquarters.

MONDAY, SEPTEMBER 20

Exposition open from 12:00 M. to 10:00 P. M.

10:00 A. M.—Technical Session, Ball Room, Drake Hotel.
12:00 M.—Exposition opens, Registration begins, Municipal Pier.
2:00 P. M.—Technical Session, Ball Room, Drake Hotel.

TUESDAY, SEPTEMBER 21

Exposition open from 10:00 A. M. to 10:00 P. M.

9:00 A. M.—Technical Session, Drake Hotel.
10:00 A. M.—Exposition opens.
12:15 P. M.—Metallurgical Educational Luncheon, Drake Hotel.
1:30 P. M.—Plant inspection.
2:00 P. M.—Technical Session, Ball Room, Drake Hotel.
9:30 P. M.—Grand Ball, Ball Room, Drake Hotel.

WEDNESDAY, SEPTEMBER 22

Expsoition open from 10:00 A. M. to 6:00 P. M.

9:30 A. M.—Annual Meeting of A.S.S.T., Ball Room, Drake Hotel.
10:30 A. M.—E. D. Campbell Memorial Lecture, Ball Room, Drake Hotel.
1:30 P. M.—Plant inspection.
2:00 P. M.—Technical Session, Ball Room, Drake Hotel.
6:00 P. M.—Exposition closes for the day.
9:30 P. M.—Smoker and Annual Frolic, Riding Academy.

THURSDAY, SEPTEMBER 23

Exposition open from 10:00 A. M. to 6:00 P. M.

9:30 A. M.—Technical Session, Ball Room, Drake Hotel.
10:00 A. M.—Exposition opens.
2:00 P. M.—Technical Session, Ball Room, Drake Hotel.
6:00 P. M.—Exposition closes for the day.
6:30 P. M.—Annual Banquet, Ball Room, Drake Hotel.

FRIDAY, SEPTEMBER 24

Exposition open from 10:00 A. M. to 10:00 P. M.

9:30 A. M.—Technical Session, Ball Room, Drake Hotel.
10:00 A. M.—Exposition opens.
1:30 P. M.—Plant inspection.
2:00 P. M.—Technical Session, Drake Hotel.
10:00 P. M.—Official close of the exposition.

Inspects St. Louis Stack

About 75 foundrymen from St. Louis and the surrounding region were guests on June 22 and 23 of the St. Louis Coke & Iron Company. On the first day the party inspected the company's new blast furnace at Granite City, which is nearing completion, and the coke ovens and by-product departments.

All the steel work of the new blast furnace has been completed. Construction will be finished early in September, and it is expected to have the furnace in blast some time during that month. The new output will have a capacity of 600 tons daily, which will bring the total output up to 1,100 tons.

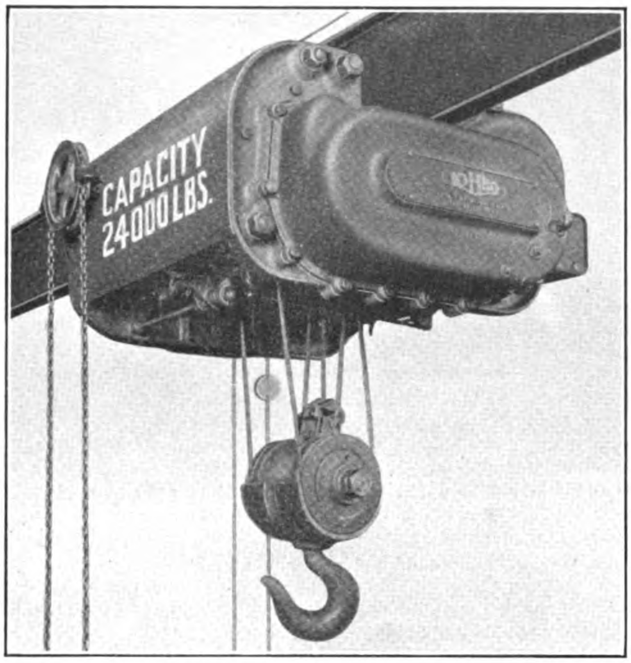
Otis Steel Pays Up Back Dividends

Stockholders and directors of the Otis Steel Company have given final approval of the refinancing plan of the company which provides for the payment to stockholders of five years' accumulation of dividends on the preferred shares. The company will pay the bulk of the accrued dividends in a new issue of prior preference stock, together with $1.75 a share in cash. Over 75 per cent of the stockholders of the company in number and 85 per cent of the amount of stock have approved the plan.

NEW EQUIPMENT SECTION

Six New Lo-Hed Electric Hoists

Six new electric monorail hoists, ranging in capacities from three to 12 tons, are announced by the American Engineering Company, of Philadelphia, as additions to its line of Lo-Hed hoists. Each of these new hoists is made in types for bolt suspension, hand geared trolley, motor trolley and cab control. Open cabs are provided for indoor use and closed cabs for outdoor service. The hoists can also be supplied with push-button control or remote control. Foundry-type control is provided when desired.



Lo-Hed Electric Hoist

These hoists, which are designated as "Class J, Lo-Hed" electric hoists, embody the same principles of design that characterize the other models of Lo-Hed hoists, with such additional features as are made necessary by the higher speeds at which they operate and the heavier loads they are designed to handle. Rated capacities are 3, 5, 6, 8, 10 and 12 tons, so that the complete Lo-Hed line now includes hoists from ½-ton to 12-ton capacity.

In all Lo-Hed hoists the drum and motor are placed on opposite sides of the I-beam track, so that the load block can be drawn up between them until it almost touches the rail. This utilizes all the available headroom and enables these hoists to handle larger loads and stack goods higher than would be possible for any hoist requiring more headroom in which to operate.

The hoist operates on standard I-beams, through switches and around curves. Hyatt roller bearings on the trolley wheels and ball thrust bearings between the wheels and the trolley frames, combined with the straight spur gear drive and the fact that wheels on both sides of the I-beam are driven, make the hoist move easily along the rail. The trolley trucks are swiveled for going around curves of short radius.

The ball-bearing hoisting motor is totally enclosed and drives the drum by spur gears running in oil. Hyatt bearings are provided on the ends of the shafts. The working parts are accessible for inspection and care by simply removing the cover of the hoist. The compact design eliminates all need for long shafts. Motor and pinion can be removed as a unit without taking off the gear cover or draining the oil from the gears. A swivel hook on the load block makes it easy to turn the load and guide it. Safety features include a factor of safety of five in the design of the hoist; upper limit stop and a powerful, quick-acting brake that is automatically applied the instant the current is turned off, either accidentally or intenionally, and stops all movement of the load without drift.

New Special "Pyro-porus" Gas Filter

Gas filtration is unquestionably the most important problem in connection with flue gas analysis. The standard Pyro-porus filter, as illustrated in Fig. 1, is well adapted to exclude soot and fine ash, from the sampling line in ordinary boiler practice. This filter is placed on the end of the gas sampling line within the boiler or flue and as the hot gases enter it the soot and ash deposit on the outer surfaces of the porous refractory discs. Such deposit, being in itself very porus, does not interfere with gas flow, hence the discs require no cleaning or replacement for years.

For certain special applications, however, the standard filter is unsuitable, because of the impingement of incandescent particles of ash against the discs, which action seals the pores by causing a slag film to form over the surface of the discs, shutting off the gas flow. This is likely to happen in cement kilns and in certain metallurgical processes. It can also happen when burning fine coke braize on chain grate stokers or powdered fuel by air blast. In the latter cases the particles of ash may be in a molten condition when they strike the filter, even though the filter

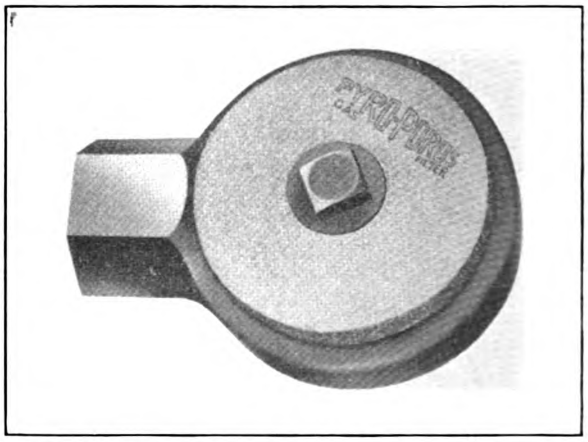


FIG. 1—Standard "Pyro-Porus" Filter.

is located in a position in the last pass where the flue gas temperature is not over 400 or 500 deg. F.

This slagging action is completely prevented and the filtering discs protected indefinitely against sealing up by means of metal shields which are now applied to a new special Pyro-porus filter. Fig. 2 is a sectional view of the new filter, arrows indicating the gas flow through the porus discs D. The shields which protect the porous discs against direct impingement of molten particles are marked E. The filtering discs and shields are held together by bolt B and nut C, tight joints being secured by asbestos gaskets G and F. The weight of the filter casting A is supported in the boiler setting by pipe J, the gas being conducted away at high velocity by the smaller pipe H within it.

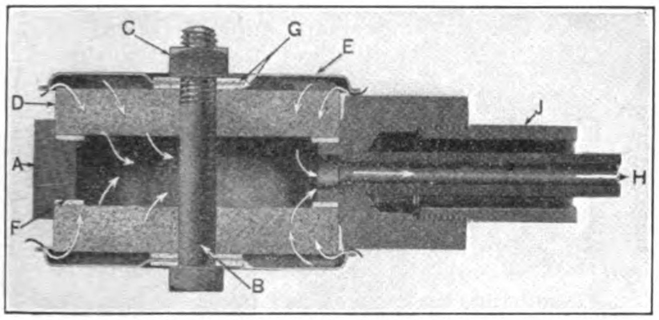
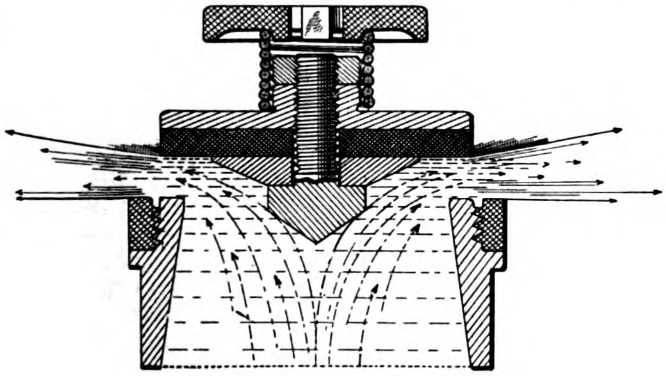


FIG. 2—Sectional view of filter.

This filter is made by the Uehling Instrument Company, 473 Getty Avenue, Patterson, N. J., and the manufacturer guarantees it to work effectively under any conditions between 200 and 1400 deg. F. For higher temperatures, other special features are necessary.

Stream Line Pump Valve

A refinement in pump valves announced by the Williamsport Bullen Pump Valve Company. Its designers and makers have skillfully combined in this valve all of the features that are essential to maximum efficiency. The valve is exceedingly strong and sturdy, of simple construction, having but four parts. To assure sensitivity it is made as light as possible so that its action is practically instantaneous; therefore clippage is cut almost to zero and leakage troubles are eliminated.



Stream Line Pump Valve

One of the features of the valve is the elimination of web pieces from the inside of the valve. By removing the webs the velocity is reduced and efficiency is therefore bettered considerably.

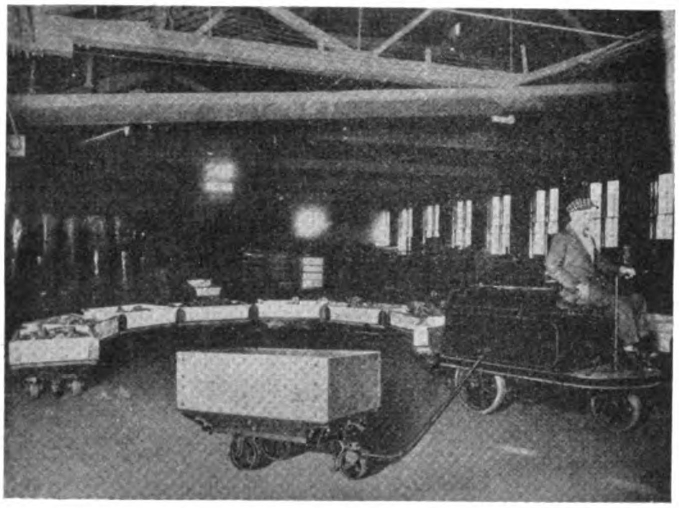
To eliminate the possibility of broken studs a Tobin bronze is used in this valve. By making the interior as smooth as practicable, and eliminating abrupt turns, fluid friction is reduced to the minimum, thus increasing the overall efficiency of the entire pump.

The valve body is made of government bronze, while the disc, usually made of "Wigaco," can be made of any material suitable for whatever the special pumping problem may be.

The Howe Truck

The Howe truck, manufactured by the Howe Chain Company, Muskegon, Mich., was designed for the rehandling of products in the course of manufacture, as well as being a help in the economizing of labor in various industrial situations. Obviously it finds its greatest usefulness as a material conveyor in plants, handling loose, bulk, package or heavy piece equipment up to 6,000 pounds in weight.

It consists of a hardwood platform equipped with two malleable iron wheels permanently attached at the rear, and a malleable iron draw bar in front. A jack tongue, which contains the third wheel, when held in a vertical position hooks into the draw bar from either the front or the side, rendering the truck instantly and easily movable. As it is lowered, it exerts a cam action on the draw bar, elevating the leg 1¼ in. off the floor, and placing the forward weight of the truck on the jack tongue wheel instead of on the leg.



Howe Industrial Truck

For convenience in moving empty trucks, or those with comparatively light loads, a permanent handle integral with the draw bar jacket is provided on each truck. For trailer purposes the jack tongue is superseded by a trailer hitch, which is substantially the same in principle as the jack tongue.

Some of the more popular models are built in different types, viz: with flat standard hardwood platform; with wood tray body on standard platform; with steel tray body on standard platform; with flush steel covered platform; and with a steel rack body, this latter composed of channel iron members, securely riveted to the angle ends.

PERSONALS

Malcolm Findlay McConnell, the new general superintendent of the Mingo and Bellaire Works of the Carnegie Steel Company, was born in New Castle, Pa., November 3, 1880, son of Malcolm and Francis E. Findlay McConnell. He was educated in the grade and high schools of New Castle, and in 1902 graduated as mechanical engineer from the University of Pittsburgh, then the Western University of Pennsylvania.

His first employment was also his entry into the steel business, going with the National Steel Company's Sharon Works in 1900. He joined the Carnegie Steel Company's operating staff as steam engineer at the New Castle Works, January 1, 1905; and July 1, 1909 he was made assistant general superintendent of the Mingo Works where he has since been most active.

Malcolm F. McConnell

Mr. McConnell married Miss Jean Norris of New Castle, April 16, 1908, and has one young son. He is a member of the Order of Elks, the Presbyterian Church of Steubenville, and the Steubenville Country Club, while his professional associations are memberships on the American Society of Mechanical Engineers; Engineers Society of Western Pennsylvania, and the American Iron and Steel Institute.

* * *

George W. Vreeland, assistant general superintendent of Mingo and Bellaire Works of the Carnegie Steel Company, was born September 23, 1875 at Passaic, N. J., a son of George and Mary Paul Vreeland. He was educated in the public schools of New York City and studied two years in College of the City of New York, and attended night course at Cooper Union, while working in New York City. His first job was with the Garvin Machine Company, New York City where he was for fifteen months before entering Cornell University. He graduated from Cornell University as mechanical engineer, specializing in electrical engineering and chemistry, and his first job was with the Carnegie Steel Company where he went immediately after his graduation in 1898.

George W. Vreeland

While with the Cambria Steel Company, he was draftsman for three months, and for nine months, he was steam and experimental engineer, and was master mechanic of the blast furnace department for two years, and during the latter period, he supervised the erection of two blast furnaces, engine and boiler houses, river dam, and the general rebuilding of the plant. He came to the Carnegie Steel Company September 1, 1901 as master mechanic of the blast furnace at the Duquesne Works, where he assisted in designing and erecting blast furnaces, 5 and 6. He was made assistant superintendent of blast furnaces at Duquesne Works in 1904, and in 1908, he was made superintendent of blast furnaces of the Mingo, Bellaire and Steubenville Works. On July 1 he was appointed assistant general superintendent.

* * *

Chester P. Clingerman, superintendent of blast furnaces of the Mingo and Bellaire Works of the Carnegie Steel Company, was born March 12, 1884 at Altoona, Pa., son of John and Rebecca Clingerman. He attended the grade and high schools of Altoona and in 1906 graduated with the degree of mechanical engineer from Lehigh University. During his collegiate course he was employed by the H. C. Frick Coke Company, at its Everson Shops which was his first job. In July 1906 he went with the Carnegie Steel Company, as recorder in the merchant mills at the Duquesne Works. In April 1907 he went to the National Works of the National Tube Company as draftsman, and later became master mechanic. In November 1909 he went to the blast furnace department of the Duquesne Works of the Carnegie Steel Company, serving successfully as clerk, blower and turn foreman. In March 1915 Mr. Clingerman went with the Bethlehem Steel Company being located at its Sparrow Point plant, and in July 1917 he returned to the Carnegie Steel Company as assitant superintendent of blast furnaces at the Bellaire plant, where he remained until his present appointment.

Chester P. Clingerman

* * *

Floyd Rose, who has been elected vice president of the Vanadium Alloys Steel Company, Latrobe, Pa., resigned July 1 as secretary and general manager of sales of the Heppenstall Forge & Knife Company, Pittsburgh, Pa. His business career began in 1896 with the Carbon Steel Company, Pittsburgh, where he remained for 11 years, and through different promotions became assistant general superintendent. He left Pittsburgh in 1907, and became general superintendent of the Portsmouth Steel Company, Portsmouth, Ohio. After two years he resigned, and came back to Pittsburgh, where he engaged in the metallurgical and inspecting engineering business as Floyd Rose & Company. He was in the Pittsburgh district ordnance office, during the World War, and was in charge of the production of gun forgings at the Heppenstall Forge & Knife Company, Carbon Steel Company and the Edgewater Steel Company. At the end of the war, he was made secretary and general manager of sales of the Heppenstall Forge & Knife Company. The Heppenstall Company gave a farewell dinner to Mr. Rose, June 24.

* * *

Charles M. Schwab, chairman, Bethlehem Steel Corporation, New York, has been nominated for the presidency of the American Society of Mechanical Engineers for 1927, according to the announcement of the nominating committee which met recently in Chicago. Nominees for vice presidents were Charles L. Newcomb, manager, Dean Works, Worthington Pump & Machinery Corporation, Holyoke, Mass.; E. O. Eastwood, professor of mechanical engineering, University of Washington, Seattle; and E. R. Fish, vice president, Heine Boiler Company, St. Louis. Candidates for managers were Paul Doty, chairman of board, Minnesota State Board of Registration, St. Paul, Minn.; Ralph E. Flanders, manager, Jones & Lamson Machine Company, Springfield, Vt.; and Conrad N. Lauer, treasurer and general manager, Day & Zimmerman, Inc., Philadelphia. Erik Oberg, editor of "Machinery," New York, was the committee's choice for treasurer. Election will be by mail ballot of the entire membership, closing September 28.

* * *

Joseph Ghandy, assistant general superintendent, Tata Iron & Steel Company, Jamshepur, India, who is in this country on a tour of American steel plants, was in Pittsburgh recently. F. K. Bennett, superintendent of rolling mills of the company, who is on leave, is accompanying Mr. Ghandy on many of his plants visits.

* * *

R. H. Clarke, vice president of the Otis Steel Company, Cleveland, was elected a director of the company at the directors' meeting June 30. Ludwig Kemper, treasurer, also was made a director.

* * *

J. E. Hanson who recently joined the research department of the Ferro Enameling Supply Company, Cleveland, for the past six years had been with the Mellon Institute of Industrial Research at Pittsburgh. He was graduated from the University of Illinois, in 1920. Mr. Hanson was chairman of a special committee in the enamel division of the American Ceramic Society on furnaces for cast iron enameling.

* * *

Frank F. Chiles has become affiliated with the sales department of the McKinney Steel Company, Cleveland and will give special attention to the marketing of bar products. The McKinney company now is completing new bar capacity and will engage in this line of production in the near future.

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W. S. Jones has resigned as vice president and director of the Vanadium-Alloys Steel Company, Latrobe, Pa., makers of high speed carbon and alloy tool steels.

* * *

Arthur W. Thompson, Pittsburgh, has been elected president of the United Gas Improvement Company, Philadelphia, to succeed Samuel T. Bodine who was elected chairman of the board. Thompson had been president of the Philadelphia Company and its affiliated public utility companies.

* * *

William T. Shepard, resident vice president of Rogers Brown & Crocker Bros., Inc., at Buffalo, N. Y., retired July 1, being succeeded by R. T. Melville, who assumes these duties with offices at 316 Erie County Bank Building.

* * *

Philip L. Coddington has joined the New England sales organization of the Ludlum Steel Company, Watervliet, N. Y. He will assist E. R. S. Reeder, New England manager of sales at 1004 Little Building, Boston.

Frank F. Corby, who recently joined the sales force of the A. M. Byers Company, Pittsburgh, as its Pacific coast representative with headquarters in Los Angeles, formerly was vice president in charge of sales of the Steel & Tube Company of America.

* * *

Col. George J. Siedler, Havenford, Pa., has been elected president of the Princeton Engineering Association. Colonel Siedler graduated from Princeton University in 1900. He became sales manager of the Taylor-Wharton Iron & Steel Company, and later was vice president of Eynon-Evans Mfg. Company, Philadelphia. He had charge of sales promotion for the Vim Motor Truck Company for a time and in larger connections served as assistant to the president of the Standard Supply & Equipment Company as president of the Remington Sales Corporation and president of the Edwards Company, Philadelphia. Colonel Siedler is now engaged in consulting sales work.

* * *

L. F. Kuhman has been appointed vice president and director of the Andrews-Bradshaw Company, Pittsburgh, sales manager for a steam purifier and gas and vapor scrubber. Mr. Kuhman has been associated with the company for the past three and a half years. For eight years prior to that time he was sales engineer for the Ingersoll-Rand Company in the Pittsburgh district. He formerly attended Carnegie Institute of Technology, Pittsburgh.

* * *

C. L. Wade has been appointed sales agent, and S. P. Buffini has been made assistant manager of the wire fence department of the Pittsburgh Steel Company, both being located in the company's general offices at Pittsburgh.

* * *

D. W. McGeorge has been appointed sales engineer of the Birdsboro Steel Foundry & Machine Company, Birdsboro, Pa., manufacturer of hydraulic presses, rolling mill machinery, special machinery, steel castings and rolling mill rolls, etc. Mr. McGeorge was previously connected with the sales department of the Edgewater Steel Company, Pittsburgh, Pa.

* * *

Charles J. Murray has recently resigned from staff of The Linde Air Products Company, to become associated with the Oklahoma Contracting Company. He is now organizing a new division of that concern to engage exclusively in oxwelded pipe line construction. During his association with the Linde Company, Mr. Murray specialized in this class of work and has studied the construction problems connected with a large number of notable trunk line projects.

* * *

C. W. Fisher, for two years associated with the McMyler Interstate Company in the sales engineering department at Cleveland, has just been named to head the Chicago branch of the firm. In his new capacity as Chicago manager, Mr. Fisher will have charge of engineering and sales on the standard products of the McMyler Interstate Company for the Upper Mississippi district, which included Illinois, Wisconsin, and parts of Minnesota and Nebraska.

* * *

MacDonald C. Booze, senior fellow of the Multiple Industrial Fellowship which is sustained by the American Refractories Institute at Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa., has resigned to accept a position with the

Charles Taylor Sons Company, Cincinnati, Ohio, as vice president in charge of research and development. Mr. Booze, who has been very active in the refractories industry since 1924, when he became a member of Mellon Iinstitute, has contributed valuably to the knowledge of refractories and their uses.

* * *

Frank Herzog was appointed chief draftsman, Wickwire Spencer Steel Company, Buffalo, N. Y., effective July 1. K. H. Marsh is chief engineer and James C. Hott is combustion engineer.

* * *

Stuart M. Phelps, who has been employed on the Refractories Fellowship since 1918, has been appointed director of research of the American Refractories Institute, effective July 1, 1926. Mr. Phelps will have charge of the investigational and testing activities of the Fellowship.

* * *

B. M. Horter, formerly of the Philadelphia office of the Cutler-Hammer Mfg. Company, has just been appointed manager of the company's Boston office. He succeeds Mr. J. M. Fernald, who has resigned to enter a different field of business. Mr. Horter has been with the Cutler-Hammer Mfg. Company, since March, 1916. At one time, Mr. Horter was manager of the Wilkes-Barre office of Cutler-Hammer, which has since been discontinued. During the war, Mr. Horter served on a submarine chaser.

* * *

Raymond Fink, who has been vice president of Pierce, Butler & Pierce, has joined the executive staff of The Sherman Corporation, engineers.

* * *

Walter F. Ingalls has been elected president of the Central Tube Company.

OBITUARIES

George A. St. Clair, for many years identified with Lake Superior iron mining and prospecting, died at Duluth, June 19, aged 77 years.

* * *

George W. Machlet, president American Gas Furnace Company, Elizabeth, N. J., died on June 25. He was born May 23, 1835, in Pforzheim, Baden, Germany.

* * *

Philip Zeurner, aged 72, of North Braddock, Pa., died suddenly in his home July 10.

* * *

Cl. Lingo, for 25 years traffic manager of the Inland Steel Company, Chicago, and a prominent figure in recent years in traffic matters before the Interstate Commerce Commission and various middle western state commissions, died July 1 at the age of 60.

Industrial Business Changes

Federal Oil Burner Manufacturing Company, Bridgeport, Conn., manufacturer of oil burning equipment, has changed its name to Cameo Oil Burner Manufacturing Company.

TRADE NOTES

Merger of the Central Steel Company of Massillon, Ohio, and United Alloy Steel Corporation of Canton, Ohio, with assets exceeding $80,000,000 under the name of the Central Alloy Steel Corporation, was announced through Otis & Company, of Cleveland, July 15, after directors of the two companies voted approval of the proposal. A stockholders' meeting was called immediately.

The merger will be effected through an exchange of stock that will give Central Steel common holders 2⅛ shares of new stock and United Alloy common an even share for share exchange.

The new board of directors has not been announced, but it is assumed the Eaton-Mather interests of Cleveland, who have been exercising financial sponsorship, inclusive of actual control of United Alloy, will continue in that relationship in the new combination.

F. J. Griffiths becomes chairman of the board; C. E. Stuart, president and treasurer; B. F. Fairless, vice president and general manager; J. H. Schlendorf, vice president in charge of sales, and C. W. Krieg, secretary.

All except Krieg, who is with the Alloy company, are officials of the present Central Steel company.

Harroy Coulby, present Alloy chairman, stated for himself and associates that he was greatly pleased with the merger and felt that unified management would result in material economies directly benefiting shareholders.

Chairman Griffiths said that no radical changes would take place, but that efforts would be centered upon cementing and building up the two companies into an organization unexcelled in the industry.

* * *

Morgan Construction Company, Worcester, Mass., announce that they have received orders for producer gas machines from the following companies which, with one exception, are repeat orders: Youngstown Sheet & Tube Company 9, Weirton Steel Company 10, Sharon Steel Hoop Company 4, American Steel & Wire Company 2, and Bethlehem Steel Company 3.

* * *

The Phoenix Iron Company of Phoenixville, Pa., has contracted with the Chapman-Stein Furnace Company of Mt. Vernon, Ohio, for a continuous recuperative billet heating furnace. It is to be furnished complete with stack and end discharge type, and when built will be approximately 66 feet long by 23 feet wide. Billets 8 in. square by 18 ft. long will be heated. The capacity of the furnace is 40 tons per hour. Oil will be used as fuel.

* * *

Molybdenum Corporation of America, Pittsburgh, has discontinued the position of chairman of the board and has re-elected former officers. J. W. Weitzenkorn was continued as president; Mary Hirsch, vice president; James S. Crawford, secretary-treasurer, and William B. Kuntz, assistant treasurer.

* * *

Frederick C. Mathews Company, Detroit; Process Metal Stamping Company, Detroit, and St. Thomas Metal Signs, Ltd., St. Thomas, Ont., have been merged under the title of Mathews Industries, Inc., with $1,000,000 capital. Plants will be enlarged.

* * *

The A. M. Byers Company, Pittsburgh, announces the consolidation of the Cincinnati and Cleveland sales districts into the Central District, with George E. Clifford in charge, with headquarters at Cincinnati.

COMING MEETINGS

September 20-24 — American Society for Steel Treating. Annual Convention and National Steel and Machine Tool Exposition at Municipal Pier, Chicago, Ill. W. H. Eisenman, 4600 Prospect Avenue, Cleveland, Ohio, secretary.

* * *

Sept. 27-Oct. 1—American Foundrymen's Association. Second international foundrymen's congress, Detroit. R. E. Kennedy, secretary, 909 W. California Street, Urbana, Ill.

TRADE PUBLICATIONS

Push Button Master Switch—The Ohio Electric & Controller Company, Cleveland, Ohio, have just published a four-page leaflet which describes in detail a push button switch for the operation of a magnetic contactors used in connection with lifting magnets.

* * *

Hand Cranes—Herbert Morris, Inc., Buffalo, N. Y., are distributing catalog No. 104, describing their various models of hand operated cranes. A number of installations are illustrated in the catalog.

* * *

Coal Burning Equipment—The Combustion Engineering Company, New York, N. Y., has just published a new catalog describing and illustrating their C-E Unit System for burning pulverized coal.

* * *

Steel Castings—Walworth Company, Boston, Mass., discusses in bulletin No. 9 standardized shrink head practice that they have adopted in their steel foundry to assure sound castings.

* * *

Cranes—Orton Crane & Shovel Company, Chicago, Ill., are distributing a 24-page bulletin in No. 41 illustrating and describing their Models "T" and "E" converting cranes with attachments.

* * *

Cranes—Foundry Equipment—New 48-page condensed catalog No. 175, recently published by the Whiting Corporation, Harvey, Ill., describes their standard line of cranes, foundry equipment and railing specialties.

* * *

Factory Furniture—Hughes Steel Equipment Co., Allegan, Mich., have issued a 32-page booklet covering their line of steel furniture and equipment for office and factory. A complete line of pressed steel tools, chairs, tables, trucks and bench legs is described.

Electrical—General Electric Company, Schenectady, N. Y., has published four pamphlets describing various equipment for power installations. The pamphlets include two on squirrel cage motors, one on explosion chambers for oil circuit breakers and one on automatic starting compensators for induction motors.

* * *

Insulation—Celite Products Company, New York, has issued a leaflet covering its insulating material and a special concrete produced by mixing the insulating material with ordinary concrete. Practical application of these materials is shown in the illustrations.

* * *

Dial Thermometers—Foxboro Company, Inc., Foxboro, Mass., has issued a bulletin covering its indicating dial thermometers for long-distance reading. They bring the reading of distant temperatures to the office of the executive.

* * *

Pyrometers—Bowen Instrument Company, Leeds, England, has published a pamphlet describing its radiator pyrometer for determining temperatures over 500 deg. C. Construction, principles of operation and the advantages of this type of instrument are enumerated.

* * *

Magnet Controller—Ohio Electric & Controller Company, Cleveland, has issued a leaflet describing in detail its newly developed push button master switch for operation of magnetic contactor for lifting magnets. Connection diagrams make clear the construction and operation of the device.

* * *

Electrical Control—A booklet on industry's electrical progress has been issued by the Cutler-Hammer Manufacturing Company, Milwaukee. Its text is the proposition that the advantages of electric power to industry lies largely in the effectiveness with which it is utilized. With increase in consumption of electricity of 3000 per cent since 1905, the booklet points out the progress also made in equipment, motors and motor control apparatus.

* * *

Optical Pyrometers—The Bacharach Industrial Company, 7000 Bennett Street, Pittsburgh, Pa., are distributing bulletin No. 293, describing the Holburn-Kurlbaum optical pyrometer. The bulletin discusses the measurement of high temperatures, black body and non-black body radiation; the principle and operation of the H-K optical pyrometer and applications and method of making determinations and corrections.

* * *

Lubricators—The Keystone Lubricating Company, Twenty-first and Clearfield Streets, Philadelphia, Pa., recently issued a 48-page booklet entitled "The Keystone Safety Lubricators; Questions Answered and Typical Installations Illustrated." The booklet thoroughly discusses the lubricator, its purpose, method of operation, relation to safety, adaptability, etc. Various types of installation are discussed and illustrated together with the accessories that have been designed to reduce the time of lubrication attention as close as possible to zero.

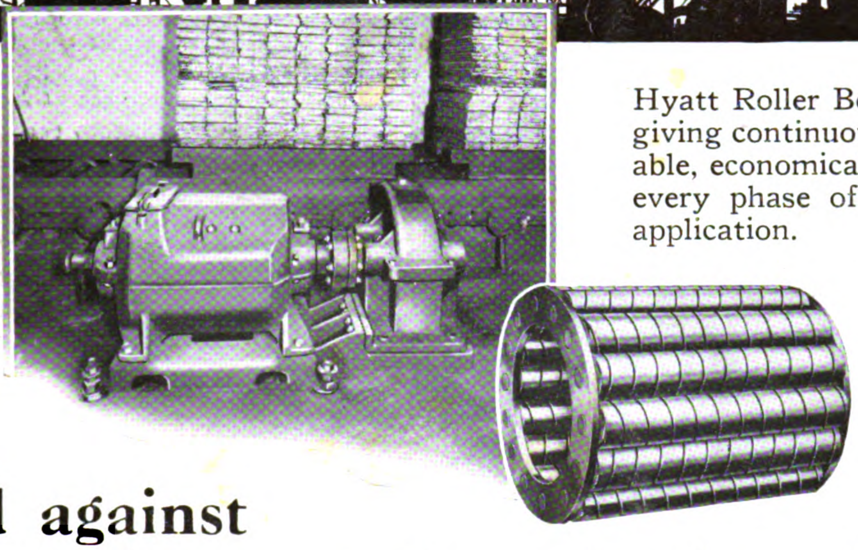
AUG 9 1926

The Blast Furnace and Steel Plant

Member of the Audit Bureau of Circulations

PITTSBURGH, PA., AUGUST, 1926

Entered as second class mail matter at Pittsburgh, Pa., under the act of Congress, March 3, 1879.



Hyatt Roller Bearings are giving continuous, dependable, economical service in every phase of steel mill application.

Guard against shut-downs and production slumps

PLAIN bearings encourage friction. Machines equipped with them start life handicapped. And end life prematurely.

Hyatt Roller Bearings, in contrast, reduce friction 50%. They reduce maintenance and labor costs 85%. They keep gears in proper mesh and prolong life immeasurably.

In motors, reduction gears and in various other steel mill applications, Hyatt bearings are giving long, hard service—without repairs or replacements.

They work shoulder to shoulder with the other mechanical parts, and do not flinch under load. They require little attention—even after 10 or 15 years of constant service. Only infrequent lubrications.

Bulletins 1825 and 705 give the interesting details.

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Philadelphia Charlotte Pittsburgh Cleveland

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